HUMAN PHYSIOLOGY.

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Part I

WITH WHICH IS INCORPORATED,

MUCH OF THE ELEMENTARY PART OF THE

INSTITUTIONES PHYSIOLOGICÆ

OF

J. F. BLUMENBACH, M.D. F.R.S.

PROFESSOR IN THE UNIVERSITY OF GÖTTINGEN.

ILLUSTRATED WITH NUMEROUS WOOD-CUTS.

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TO

THE STUDENTS

OF THE

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THIS WORK

IS

AFFECTIONATELY INSCRIBED.

PREFACE.

In 1815, I translated the third edition of Professor Blumenbach's "Institutiones Physiologicæ," anonymously, with the addition of twenty pages of notes; the whole amounting to two hundred and sixty pages.

In 1817, I published a second edition, with my name, and the addition of a hundred and fifty pages of notes; the whole amounting to four hundred and twenty-six pages.

In 1820, I published a third edition, with two hundred pages of notes, in smaller type than the text; so that, although the whole amounted to four hundred and sixty-five pages, the matter of my notes very nearly equalled that of the text.

In 1824, I published a fourth edition, from a new edition which had appeared of the original work in 1821. The notes, still in smaller type, filled three hundred and fifty pages, and the whole amounted to five hundred and eighty-one; so that the matter of my notes greatly exceeded that of the text.

Finding that, in the present edition (which, through my engagements, has been delayed long after the preceding was out of print), my own matter would very much exceed that of Blumenbach, and that much of the original would require emendation on account of recent discoveries or might be better omitted, and that the disjointed nature of the work would be a source of greater inconvenience to the reader than ever, I resolved to remodel the whole, omitting many parts of the original, and blending my notes with as much of it as I could retain: and as the portions of the original retained are of so much smaller amount than my own labours, and of a very elementary character, and the proportions of Blumenbach's share and my own thus completely reversed, I feel satisfied that, in now giving my own name to the work, I shall be justified in the eyes of even the celebrated and venerable Blumenbach, who, though eighty-three years of age, still delivers his lectures at eight o'clock every morning. The passages with inverted commas and no farther intimation are from Blumenbach. I have illustrated many pages with woodcuts, from Dr. Jules Cloquet's collection, for the sake of the general reader: since works of this description are now read as much out of the profession as by medical men.

The correction of any errors, and the communication of any facts, either publicly or privately, will always be esteemed by me a valuable favour.

37. Conduit Street,
Feb. 14. 1835.

HUMAN PHYSIOLOGY.

I. GENERAL PHYSIOLOGY.

CHAPTER I.

GENERAL VIEW OF THE OBJECTS OF NATURE, AND OF MAN AS DISTINGUISHED FROM THE REST.

NUMEROUS authors have remarked that a gradation exists among all the objects of the universe, from the Almighty Creator, through archangels and angels, men, brutes, vegetables, and inanimate matter, down to nothing.

> "Vast chain of being which from God began,
> Natures ethereal, human, angel, man,
> Beast, bird, fish, insect, what no eye can see,
> No glass can reach, from infinite to thee,
> From thee to nothing." [a]

Yet this gradation, striking as it is, deserves not the epithet regular or insensible. "The highest being not infinite must be, as has been often observed, at an infinite distance below infinity." "And in this distance between finite and infinite there will be room for ever for an infinite series of indefinable existence. Between the lowest positive existence and nothing, wherever we suppose existence to cease, is another chasm infinitely deep; where there is room again for endless orders of subordinate beings, continued for ever and ever, and yet infinitely superior to

[a] Pope, *Essay on Man*, Epistle I.

non-existence." "Nor is this all. In the scale, wherever it begins or ends, are infinite vacuities. At whatever distance we suppose the next order of beings to be above man, there is room for an intermediate order of beings between them, and if for one order then for infinite orders; since every thing that admits of more or less, and, consequently, all the parts of that which admits them, may be infinitely divided. So that, as far as we can judge, there may be room in the vacuity between any two steps of the scale, or between any two points of the cone, for infinite exertion of infinite power." [b]

In fact, at how vast a distance do we see the innate mental properties of man standing above those of the most sagacious brute! How immensely does the volition of the lowest animal raise it above the whole vegetable kingdom! And how deep the chasm between the vital organisation of the meanest vegetable and a mass of inanimate matter! Gradation must be admitted, but it is far from regular or insensible. Neither does it at all regard perfection of system, nor very much the degree, but chiefly the excellence, and, within the limits of the visible world, the combination, of properties. Man, placed at the summit of terrestrial objects by the excellence of his mind and the combination of the common properties of matter, of those of vegetables, and of those of brutes, with those peculiar to himself, is surpassed by the dog in acuteness of smell and by the oak in magnitude, nor can he boast of more perfection than the gnat or the thistle in their kinds.

Substances consist of Particles endowed with certain properties without which their existence cannot be conceived, *viz.* extension and impenetrability; with others which proceed, indeed, from their existence, but are capable of being subdued by opposing energies, *viz.* mobility, inertness; and with others apparently neither necessary to their existence nor flowing from it, but merely superadded: for example, various attractions and repulsions, and various powers of affecting animated systems.

Inanimate substances may be gaseous, liquid, or solid. If solid, the inanimate body has no properties which are not analogous to these, or even dependent upon them. It is for the most part

[b] Dr. Johnson, *Review of a Free Enquiry into the Nature and Origin of Evil.*

homogeneous in its composition, and disposed to be flat and angular, increases by external accretion, has an indeterminate volume, and contains within itself no causes of decay. The rest of the bodies in nature are *animated*, and are vegetables and animals.

VEGETABLES, in addition to the properties of inanimate matter, possess those of LIFE, *viz.* sensibility (without consciousness or perception) — I would say excitability, for sensibility without the power of sensation is nonsense, — and contractility; or I would rather express both by the term excitability.[c] Their structure is beautifully organised, their volume is determinate, and their surfaces disposed to be curved; they grow by interstitial deposition, changing substances to their own nature, and are destined in their very nature for a limited existence, — a period of increase and decay. They contain fluids, some of which they receive, others they produce, and others they discharge.

ANIMALS, in addition to the properties and characteristics of vegetables, enjoy MIND, the indispensable attributes of which are the powers of consciousness and perception, and of volition: the two former, — which are in truth but one, termed consciousness when it takes cognisance of internal impressions, and perception when of external, — without the latter, would be, like vegetable or organic sensibility without contractility, were this possible, useless; and the latter could not exist without the former[d], any more than vegetable or organic contraction could occur without excitability: nor can the existence of mind be conceived without the faculties of consciousness, perception, and volition, any more than the existence of matter without extension and impenetrability. The possession of mind by animals necessarily implies the presence of a brain for its exertion, and of a nerve or nerves for the purpose of conveying impressions to this brain, and at least volitions from it to one or more voluntary muscles. A system

[c] By their possession of the former, stimuli act upon them, and by the latter, they upon stimuli: by the sensibility and contractility of the vessels, substances are taken in by the roots, circulated through the system, and converted into the various parts of the vegetable. Yet this does not imply perception, consciousness, or will. The excitability of the absorbents and secretories of our own system carries on absorption and secretion without our consciousness or volition.

[d] " *Sense*," says Hamlet to his mother, " sure you have,
Else could you not have *motion*." Act iii. Sc. 4.

which is not thus gifted certainly deserves not the name of animal.[e]

Notwithstanding the vast interval which of necessity exists between the animal and vegetable kingdoms, the lowest brutes approach as nearly as possible in organisation, and consequently in function, to vegetable simplicity. They possess merely consciousness and perception, and volition, with the appetite for food, or are even nourished by imbibition, and multiply by shoots, fixed like vegetables to the spot which they inhabit. The five senses, sexual appetite, instincts, memory, judgment[f], and loco-

[e] I cannot conceive an animal without consciousness, perception, and volition; nor can I conceive these in an animal without a brain, any more than the secretion of bile without a liver, or something analogous. I contend not for the name, but for the thing. Zoologists indeed affirm that many internal worms and all the class of zoophytes have no nervous system. But comparative anatomy is yet imperfect, the examination of minute parts is extremely difficult, and new organs are daily discovered. Blumenbach, after remarking that, except those animals which inhabit corals and the proper zoophytes, most genera of the other orders of the Linnæan class of vermes are found to possess a distinct nervous system, adds: " although former anatomists have expressly declared in several instances that no such parts existed." (*Comparative Anatomy*, ch. cxvi. F.) Besides, some beings have been denominated animals without any very satisfactory reason.

Where the nervous system of an animal cannot be readily detected, its presence may be inferred from motions evidently voluntary, such as retraction upon the approach of footsteps, — proving the existence of an organ of hearing, a brain, and nerves: motion in a part *directly* stimulated, as the contraction of an hydatid upon being punctured, is no proof of an animal nature, for this is common to vegetables, for instance, the leaves of the *dionæa muscipula*, which contract forcibly on a slight irritation. It may likewise be inferred from the presence of a stomach, because, where there is a stomach, the food is taken in, not by absorbing vessels constantly plunged in it, but by a more or less complicated and generally solitary opening regulated by volition. John Hunter contended that the stomach was the grand characteristic of the animal kingdom.

[f] I see daily instances of something deserving some such name as judgment or reason in brutes. To the incredulous I offer the following anecdote in the words of Dr. Darwin. " A wasp on a gravel walk had caught a fly nearly as large as itself. Kneeling on the ground, I observed him separate the tail and the head from the body part to which the wings were attached. He then took the body part in his paws and rose about two feet from the ground with it; but a gentle breeze wafting the wings of the fly turned him round in the air and he settled again with his prey upon the gravel. I then distinctly observed him cut off with his mouth first one of the wings and then the other, after which he flew away with it unmolested with the wind." *Zoonomia:* Instinct. — The works of the two Hubers, *Sur les Abeilles* and *Sur les Mœurs des Fourmis indigènes*, furnish

motive power, with the necessary organs, are variously superadded, and endless varieties of organisation constructed, so that air and water, the surface and the crust of the earth, are all replenished with animals completely calculated for their respective habitations.[g]

Man, besides the common properties of animals, has others which raise him to an immense superiority. His mind is endowed with powers of the highest order that brutes have not, and his body being, like the bodies of all animals, constituted in harmony

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an abundance of most interesting instances of reason in those insects. See also Mr. Smellie's paper in the *Transact. of Royal Society of Edinburgh*, vol. i. p. 39. sqq.

g An error has been committed not only in representing the gradation regular, but in supposing every species of animal to constitute a distinct step in the gradation. "The whole chasm in nature," says Addison (*Spectator*, No. 519.), "from a plant to a man, is filled up with divers kinds of creatures, rising one above another, by such a gentle and easy ascent, that the little transitions and deviations from one species to another are almost insensible." "All quite down from us," says Locke (*Essay on the Human Understanding*, b. iii. c. 6.), "the descent is by easy steps, and a continued series of things, that in each remove differ very little one from the other. There are fishes that have wings, and are not strangers to the airy region; and there are some birds, that are inhabitants of the water; whose blood is cold as fishes, and their flesh so like in taste that the scrupulous are allowed them on fish days. There are animals so near of kin both to birds and beasts, that they are in the middle between both: amphibious animals link the terrestrial and aquatic together, seals live at land and at sea, and porpoises have the warm blood and entrails of a hog; not to mention what is confidently reported of mermaids or sea men." "In respect of our intellectual and moral principles," remarks Mr. Dugald Stewart (*Outlines of Moral Philosophy*, par. 109.), "our nature does not admit of comparison with that of any other inhabitant of this globe: the difference between our constitution and theirs being a difference, not in degree, but in kind. Perhaps this is the single instance in which that regular gradation, which we, every where else, observe in the universe, fails entirely."

Now the various kinds of animals do certainly run into each other; — there are no great peculiarities of construction in single organs between which and the ordinary structure of the same organs in other animals an intermediate structure connecting the two are not continually brought to light by naturalists. No two are so different but that discoveries are continually made of a third intermediate. *But connection is not gradation.* Many kinds, and the intermediate ones by which they are united, are all on a level in point of excellence and combination of properties, so that a single step in the gradation may comprehend a great number of kinds: — the whole vegetable kingdom forms but one step.

with the mind that the powers of the latter may have effect, differs necessarily in many points of construction from the body of every brute. Well might Shakspeare exclaim, "What a piece of work is man! How noble in reason! how infinite in faculties! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god! the beauty of the world! the paragon of animals!"[h]

The orang utans approach the nearest of all brutes to the human subject. Possessing expression of countenance, elevation of forehead, and less projection of the lower part of the face than other brutes, anterior extremities that are really arms and hands, and teeth of the same number and pretty much of the same figure as our own; curious, imitative, covetous, social; said by some to place sentinels and dispose themselves in a train for the propagation of alarm; to seem now and then to laugh and weep[i], to walk a little occasionally erect, to defend themselves with sticks and stones, to copulate face to face, to carry their young either in their arms or on their backs, and to be very lascivious in regard to our species; — the orang utans at first sight afford, if any of the genus can afford, a little probability to the opinion of a close connection between apes and the human race. Uncivilised men, too, make a slight approach in many corporeal particulars, as we shall hereafter find, to the structure of other animals, and since, also, the circumstances of their existence call into action few of the peculiar mental powers of our nature, they have been adduced in corroboration of this opinion. But *the least examination* displays differences of the greatest magnitude between the human and the brute creation.[k] These we shall review under two divisions, the

[h] *Hamlet*, Act ii. Sc. 2.

[i] Le Cat (*Traité de l'Existence du Fluide des Nerfs*, p. 35.) asserts that he had seen the jocko or chimpanzee (*simia troglodytes*) both laugh and cry. The reader will remember the lines in Milton's Paradise Lost (B. ix.), —

> "Smiles from reason flow,
> To brute denied."

The orang utans exhibited a few years ago at Exeter 'Change, — the one a satyrus and the other a chimpanzee, — are said by their keepers to have sometimes laughed when much pleased, but never to have wept. Steller states the fact of weeping in regard to the phoca ursina; Pallas, in regard to the camel; and Humboldt, in regard to a small American monkey. Mr. Lawrence, *Lectures*, p. 236.

[k] In La Fontaine's charming fable of *Le Singe et le Dauphin*, the former

first embracing the mental, and the second the corporeal, characteristics of mankind.

In judging of the *mental* faculties of mankind[1], not merely those should be considered which an unfortunately situated individual may display, but those which all the race would display under favourable circumstances. A seed and a pebble may not on a shelf appear very dissimilar, but, if both are placed in the earth, the innate characteristic energies of the seed soon become conspicuous. A savage may in the same manner seem little superior to an orang utan, but, if instruction is afforded to both, the former will gradually develope the powers of our nature in their noble superiority, while the latter will still remain an orang utan. The excellence of man's mind demonstrates itself chiefly

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during a shipwreck, near Athens, resolves to profit by his resemblance to man, for whom the dolphin was anciently said to have a great regard. (See Pliny, *Hist. Nat.* ix. 8, 9.) In the hurry,

> Un dauphin le prit pour un homme,
> Et sur son dos le fit asseoir
> Si gravement, qu'on eut cru voir
> Le chanteur que tant on renomme.

Just before landing him, the dolphin asked whether he often saw the Piræus, to which he unfortunately replied,

> Tous les jours : il est mon ami :
> C'est une vieille connaissance.

One glance was sufficient to discover the difference between a man and a monkey.

> Le dauphin rit, tourne la tête ;
> Et, le magot considéré,
> Il s'apperçoit qu'il n'a tiré
> Du fond des eaux rien qu'une bête ;
> Il l'y replonge, et va trouver
> Quelque homme à fin de le sauver.

" The difference between the volume of the brain of the orang utan and man is as 5 to 1 : their convolutions differ considerably in number and structure ; the anterior lobes especially are narrowed into a cone, flattened above, hollowed out below, &c. and the difference is much more striking in other apes." Gall, l. c. t. vi. p. 298.

[1] In the external senses of at least smelling, hearing, and seeing, man is surpassed by brutes. Whether they have any sense not possessed by us I cannot pretend to say.

by his voice and hands. Witness the infinite variety and the depth of thought expressed by means of words: witness his great reasoning powers, his ingenuity, his taste, his upright, religious, and benevolent, feelings, in his manufactories, his galleries of the fine arts, his halls of justice, his temples, and his charitable establishments. Besides the qualities common to all animals, each of which he, like every animal, possesses in a degree peculiar to himself, and some indeed in a degree very far surpassing that in which any brute possesses them, for instance, benevolence, mechanical contrivance, the sense for music and language, and the general power of observation and inference respecting present circumstances, he appears exclusively gifted with at least feelings of religion and justice, with taste, with wit, and with decided *reflecting* faculties of comparing and reasoning into causes.

The *corporeal* characteristics of mankind are not less striking and noble.[m] Among the beings beheld by Satan in Milton's Paradise,

> "Two of far nobler shape, erect and tall,
> Godlike erect, with native honour clad,
> In naked majesty seem'd lords of all."[n]

The erect posture is natural and peculiar to man.[o] All nations walk erect, and, among those individuals who have been disco-

[m] Consult Blumenbach, *De Generis Humani Varietate Nativa.* Sect. i. De Hominis a cæteris Animalibus differentia.

[n] *Paradise Lost*, book iv. 288.

[o] There is little necessity in the present day to attempt the refutation of the ridiculous opinion that man is destined to walk on all-fours. But I do so for the purpose of displaying many peculiarities of our structure.

It is almost incredible that a thinking man could have entertained it for a moment, any more than the idea of our naturally having tails. Yet this is the fact; and, in exquisite ridicule of such philosophers, Butler makes Hudibras, after proving to his mistress by his beard that he is no gelding, fruitlessly urge his erect posture in proof that he is not a horse.

> "Next it appears I am no horse,
> That I can argue and discourse,
> Have but two legs, and ne'er a tail. —
> Quoth she, That nothing will avail;
> For some philosophers of late here
> Write, men have four legs by nature,
> And that 'tis custom makes them go,
> Erroneously upon but two.

vered in a wild and solitary state, there is no well authenticated instance of one whose progression was on all-fours. If we attempt this mode of progression, we move either on the knees or the points of the toes, throwing the legs obliquely back to a considerable distance; we find ourselves insecure and uneasy; our eyes, instead of looking forwards, are directed to the ground; and the openings of the nostrils are no longer at the lower part of the nose,—in a situation to receive ascending odorous particles, but lie behind it. Our inferior extremities, being of much greater length, in proportion to the others and to the trunk, than the posterior of brutes with four extremities, even in children in whom the proportion is less, are evidently not intended to coincide with them in movement; they are much stronger than the arms, obviously for the purpose of great support: the presence of calves, which are found in man alone, shows that the legs are to support and move the whole machine; the thigh bones are in the same line with the trunk, in quadrupeds they form an angle, frequently an acute one; the bones of the tarsus become hard and perfect sooner than those of the carpus, because strength of leg is required for standing and walking sooner than strength of arm and hand for labour; the great toe is of the highest importance to the erect posture, and bestowed exclusively on mankind; the os calcis is very large, particularly at its posterior projection, for the insertion of the strong muscles of the calf, and lies at right angles with the leg; we alone can rest fully upon it, and in fact upon the whole of the tarsus, metatarsus, and toes. The superior extremities do not lie under the trunk as they would if destined for its support, but on its sides, capable of motion in every direction towards objects; the fore-arm extends itself outwards, not forwards, as in quadrupeds, where it is an organ of progression; the hand is fixed not at right angles with the arm, as an instrument of support, but in the same line, and cannot be extended to a right angle without painfully stretching the flexor tendons; the superior extremity is calculated in the erect

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As 'twas in Germany made good
B' a boy that lost himself in a wood,
And growing to a man was wont
With wolves upon all-four to hunt."

Hudibras, part ii. canto i.

posture for seizing and handling objects, by the freedom of its motions, by the great length of the fingers above that of the toes, and by the existence of the thumb, which, standing at a distance from the fingers and bending towards them, acts as an opponent, while the great toe is, like the rest, too short for apprehension, stands in the same line with them, and moves in the same direction: were our hands employed in the horizontal posture, they would be lost to us as grand instruments in the exercise of our mental superiority. Quadrupeds have a strong ligament at the back of the neck to sustain the head; in us there is no such thing, and our extensor muscles at the back of the neck are comparatively very weak.[p] They have the thorax deep and narrow, that the anterior extremities may lie near together and give more support; the sternum too is longer, and the ribs extend considerably towards the pelvis to maintain the incumbent viscera; our thorax is broad from side to side, that the arms being thrown to a distance may have greater extent of motion, and shallow from the sternum to the spine; and the abdominal viscera, pressing towards the pelvis rather than towards the surface of the abdomen in the erect attitude, do not here require an osseous support. The pelvis is beautifully adapted in us for supporting the bowels in the erect posture; it is extremely expanded, and the sacrum and os coccygis bend forwards below: in brutes it does not merit the name of pelvis; for, not having to support the abdominal contents, it is narrow, and the sacrum inclines but little to the pubes. The nates, besides extending the pelvis upon the thigh bones in the erect state of standing or walking, allow us to rest while awake in the sitting posture, in which, the head and trunk being still erect, our organs of sense have their proper direction equally as in walking or standing; were we compelled to lie down like quadrupeds, when resting during the waking state, the different organs of the face must change their present situation to retain their present utility, no less than if we were compelled to adopt the horizontal progression; and, conversely,

p As the head is connected with the trunk farther back in brutes than in us, the small length of lever between the occipital foramen and the back of the head, and the length of the head below the foramen, require all this power; but even in us much more upholding power than we have at the back of the neck would be required for all-four progression, as the head would no longer rest upon the spine.

were their situation so changed, the provision for the sitting posture would be comparatively useless.

While some, perversely desirous of degrading their race, have attempted to remove a splendid distinction by asserting that we are constructed for all fours, others with equal perverseness and ignorance have asserted that monkeys are destined for the upright posture. The monkey tribe, it is true, maintain the erect posture less awkwardly than other brutes with four extremities, but they cannot maintain it long, and, while in it, they bend their knees and body; they are insecure and tottering, and glad to rest upon a stick; their feet, too, instead of being spread for support, are coiled up as if to grasp something. In fact their structure proves them to be neither biped nor quadruped, but four-handed, animals. They live naturally in trees, and are furnished with four hands for grasping the branches and gathering their food. Of their four hands the posterior are even the more perfect, and are in no instance destitute of a thumb, although, like the thumbs of all the quadrumana, so insignificant as to have been termed by Eustachius, "omnino ridiculus;" whereas the anterior hands of one variety (*simia paniscus*) have not this organ. The whole length of the orang utan, it may be mentioned, falls very much short of ours.

It was anciently supposed that man, because gifted with the highest mental endowments, possessed the largest of all brains. But as elephants and whales surpass him in this respect, and the sagacious monkey and dog have smaller brains than the comparatively stupid ass, ox, and hog, the opinion was relinquished by the moderns, and man was said only to have the largest brain in proportion to the size of his body. But as more extensive observation proved canary and other birds, and some varieties of the monkey tribe, to have larger brains than man in proportion to the body, and several mammalia to equal him in this particular, and as rats and mice too surpass the dog, the horse, and the elephant, in the comparative bulk of their brains, this opinion also gave way, in its turn, to that of Sömmerring, — that man possesses the largest brain in comparison with the nerves arising from it. This has not yet been contradicted, although the comparative size of the brain to the nerves originating from it (granting that they originate from it) is not an accurate measure of the faculties, because the seal has in proportion to its nerves a larger brain than the house-dog, and the porpoise than the orang utan.[q]

As the human brain is of such great comparative magnitude, the cranium is necessarily very large and bears a greater proportion to the face than in any other animal. In an European the vertical section of the cranium is almost four times larger than that of the face (not including the lower jaw); in the monkey it is little more than double; in most feræ, nearly equal; in the glires, solipedes, pecora, and belluæ, less. The faculties, however, do not depend upon this proportion, because men of great genius, as Leo, Montaigne, Leibnitz, Haller, and Mirabeau, had very large faces, and the sloth and seal have faces larger than the stag, horse, and ox, in proportion to the brain, and the proportion is acknowledged by Cuvier to be not at all applicable to birds. We are assisted in discovering the proportion between the cranium and face by the facial angle of Camper. He draws two straight lines, the one, horizontal, passing through the external meatus auditorius and the bottom of the nostrils; the other, more perpendicular, running from the convexity of the forehead to the most prominent part of the upper jaw. The angle which the latter,—the proper facial line,—makes with the former, is greatest in the human subject, from the comparative smallness of the brain and the great developement of the mouth and nose in brutes. In the human adult this angle is about from 65° to 85°; in the orang utan about from 55° to 65°; in some quadrupeds 20°; and in the lower classes of vertebral animals it entirely disappears.

Neither is it to be regarded as an exact measure of the understanding, for persons of great intellect may have a prominent mouth; it shows merely the projection of the forehead, while the cranium and brain may vary greatly in the size of other parts; three-fourths of quadrupeds, whose crania differ extremely in other respects, have the same facial angle; great amplitude of the frontal sinuses, as in the owl and hog, without any increase of brain, may increase it, and for this reason Cuvier draws the facial line from the internal table of the frontal bone.

In proportion as the face is elongated, the occipital foramen lies more posteriorly; in man consequently it is most forward. While in man it is nearly in the centre of the base of the cranium, and horizontal, and has even sometimes its anterior margin

[q] See Gall, l. c. t. ii. p. 281. sqq.

elevated; in most quadrupeds it is situated at the extremity of the cranium obliquely, with its posterior parts turned upwards, and is in some completely vertical. On this difference of situation, Daubenton founded his occipital angle.[r] He drew one line from the posterior edge of the foramen to the lower edge of the orbit, and another, in the direction of the foramen, passing between the condyles and intersecting the former. According to the angle formed, he established the similarity and diversity of crania. The information derived from it in this respect is very imperfect, because it shows the differences of the occiput merely. Blumenbach remarks that its variations are included between 80° and 90° in most quadrupeds which differ very essentially in other points.

The want of the ossa intermaxillaria has been thought peculiar to mankind. Quadrupeds, and nearly all the ape tribe, have two bones between the superior maxillary, containing the dentes incisores when these are present, and termed ossa intermaxillaria, incisoria, or labialia. But these do not exist universally in them.[s] Man only has a prominent chin: his lower jaw is the shortest, compared with the cranium, and its condyles differ in form, direction, and articulation, from those of any brute: in no brute are the teeth arranged in such a close and uniform series; the lower incisores, like the jaw in which they are fixed, are perpendicular, — a distinct characteristic of man, for in brutes they slope back-backwards with the jaw bone; the canine are not longer than the rest, nor insulated as in monkeys; the molares differ from those of the orang utan and of all the genus simia by their singularly obtuse projections.

The slight hairiness of the human skin in general, although certain parts, as the pubes and axillæ, are more copiously furnished with hair than in brutes; the omnivorous structure of the alimentary canal; the curve of the vagina corresponding with the curve of the sacrum formerly mentioned, preventing woman from being, as brute females are, retromingent; the peculiar structure

[r] *Mémoires de l'Académie des Sciences de Paris.* 1764.

[s] In a chimpanzee that died at Exeter Change a few years ago, the statement of Tyson and Daubenton was verified, — that this black ape has no intermaxillary bone. The red-haired variety (*Simia Satyrus*) has it, and is said to be destitute of nails on the hind thumbs and of ligamentum teres at the head of the os femoris, both which structures this chimpanzee possessed. The Satyrus is therefore not so near the human subject as the Troglodytes. In a simia satyrus, however, lately dissected at the Zoological Gardens, the hind thumbs possessed nails. *Proceedings, &c.* Nov. 23. 1830.

of the human uterus and placenta; the length of the umbilical chord and the existence of the vesicula umbilicalis until the fourth month; together with the extreme delicacy of the cellular membrane; are likewise structural peculiarities of the human race. The situation of the heart lying not upon the sternum, as in quadrupeds, but upon the diaphragm, on account of our erect position, — the basis turned not, as in them, to the spine, but to the head, and the apex to the left nipple; the absence of the allantois, of the panniculus carnosus, of the rete mirabile arteriosum, of the suspensorius oculi; and the smallness of the foramen incisivum, which is not only very large in brutes, but generally double, though not peculiarities, are striking circumstances.

Man only can live in every climate [t]; he is the slowest in arriving at maturity, and, in proportion to his size, he lives the longest of all mammalia; he only procreates at every season, and, while in celibacy, experiences nocturnal emissions. None but the human female menstruates.

Man, thus distinguished from all other terrestrial beings, evidently constitutes a separate species. For "a species comprehends all the individuals which descend from each other, as from a common parent, and those which resemble them as much as they do each other [u];" and no brute bears such a resemblance to man.

The knowledge of all the objects and laws of nature might be supposed to be signified by the term physiology, derived as it is from φύσις, nature, and λόγος, a discourse. But the term is restricted to vegetables and animals, and indeed solely to their functions. The knowledge of their structure is designated Anatomy; the knowledge of their functions Physiology.

Both anatomy and physiology are divided into vegetable and animal; and the latter again into brute, or comparative, and human. The subject of the present work is Human Physiology: but the functions of brutes and vegetables will frequently be mentioned.

[t] Blumenbach accounts for this, and I think justly, by the two-fold operation, of our intellect (l. c. § 18. p. 54.), and of the more accommodating nature of our frame (l. c. § 17.).

[u] Cuvier, *Discours Préliminaire aux Recherches sur les Ossemens Fossiles des Quadrupèdes.*

CHAP. II.

GENERAL VIEW OF THE CONSTITUENTS OF THE HUMAN BODY.

The *ultimate* PRINCIPLES of animal bodies, forming the distinct compounds, whether gases, fluids, or solids, are:—

Hydrogen,
Carbon,
Oxygen,
Azote,
Chlorin, iodin, fluorin?
Sulphur,
Phosphorus,
Potassium,
Sodium,
Calcium,
Magnesium, silicium?
Manganese?
Iron,
Copper?[a]

The *proximate* PRINCIPLES, or distinct chemical compounds of animal bodies, are:—

Albumen, Fibrin, Colouring matter of blood, Curd, Fatty matter, { olein, stearin, Gelatine, obtained from various textures by boiling, Matters found in the bile,—cholesterin, erythrogin, asparagin, picromel? Mucus, and probably some other products of glands at present but little understood,	Subject to great variety in different animals, &c.

[a] The ultimate principles of vegetables may be considered the same as those of animals.

Urea,	
Cystic oxide, xanthic oxide, Uric acid, Erythric acid? Purpuric acid, Oxalic acid, Acetic acid, Lactic acid, Butyric acid, Formic acid, Benzoic acid, Sulpho-cyanic acid, Sugar of milk, Sugar of diabetic urine,[b]	Not subject to variety; uniform in all instances.

[b] Vegetable proximate principles are very numerous: the following may be considered the chief: —

Sugar, Starch, Lignin, Gum, mucus, jelly, Extractive, colouring matters, bitter principles, Gluten Oils, fixed and volatile, Resins,	All subject to endless variety as occurring in different plants.

The following are constant in their character, or are peculiar to certain vegetables.

Various acids — Oxalic, citric, tartaric, malic, moroxylic, gallic, laccic, kinic, boletic, prussic, meconic, benzoic, &c.

Various alkaline bodies — Quinina, cinchonina, morphina, strychnina, brucina, delphina, picrotoxina, atropia, veratrina, hyoscyamina, &c.

Indigo,

Tan,

Suber,

Caoutchouc,

Wax,

Asparagine, ulmine, inuline, fungine, polychroite, hæmatine, nicotine, pollenine, emetine, sarcocol, olivile, medulline, lupuline, cathartine, piperine, daphnine, salicine, populine, digitaline, santonine, cafeine, hordeine, elatine, &c, &c.

The *ultimate* SOLIDS, which these principles are said to compose, are, the cellular fibre, the muscular fibre, and the nervous fibre.[c]

The *proximate* SOLIDS, said to be composed of these primary, or rather ultimate, or elementary solids or tissues, and forming the different organs, have been variously specified.[d]

Dr. Carmichael Smyth, in an admirable paper upon inflammation, considered that disease according to the structures which it affects, — the skin, cellular membrane, serous membranes, mucous membranes, and muscular fibres.[e] Dr. Pinel, some years afterwards, adopted this arrangement[f]; and Bichat at length suggested that all diseases might be considered in this manner, and he distributed the proximate solids into twenty-one kinds:—

1. Cellular,
2. Nervous, of animal life,
3. Nervous, of organic life,
4. Arterial,
5. Venous,
6. Exhalant,
7. Absorbent, with its glands,
8. Osseous,
9. Medullary,
10. Cartilaginous,
11. Fibrous (tendino-fibrous),
12. Fibro-cartilaginous,
13. Muscular, of animal life,
14. Muscular, of organic life,
15. Mucous,
16. Serous,
17. Synovial,
18. Glandular,
19. Dermoid,
20. Epidermoid,
21. Pilous.[g]

[c] See Appendix, by Dr. Copeland, to his translation of Richerand's *Nouveaux Elémens de Physiologie*, p. 553. sqq. Many writers have asserted the globular composition of various parts of the animal and vegetable frame. Lately, the cellular, muscular, and nervous structures were described as consisting of globules, and some novel views presented, by Dr. M. Edwards. (*Archives Générales de Médecine*, t. 3. Paris, 1823.) But the whole results have been denied by Dr. Hodgkin and Mr. Lister, who repeated the examination with a much superior microscope. *Philos. Magazine*, August, 1827.

Another author professes to have made still more minute discoveries than Dr. Edwards. Dutrochet, *Recherches, Anatomiques et Physiologiques, sur la Structure Interne des Animaux et Végétaux*.

[d] " The ancients divided the body into *similar* or homogenous parts, — those consisting of particles similar to one another, as the bones, cartilages, muscles, tendons, &c.; and *dissimilar*, — those composed of the similar, as the head, trunk, limbs," &c.

[e] *Medical Communications, by a Society for the Promotion of Medical Knowledge*, vol. ii. 1790. Read to the Society, Jan. 1788.

[f] *Nosographie Philosophique*, 1797.

[g] *Anatomie Générale*, t. i. p. lxxx.

This arrangement, Dr. Rudolphi remarks, is physiological rather than anatomical, and he distributes them into eight classes only: —

Cellular,	Tendinous,
Horny,	Vascular,
Cartilaginous,	Muscular, and
Osseous,	Nervous.[h]

The *ultimate* and *proximate* FLUIDS of the body, generated by its functions, whether for its own use, or for elimination from it, may perhaps be viewed as,

Aqueous,	Oleaginous,
Mucous,	Bilious,
Albuminous,	Urinous,
Fibrinous,	Seminal.

The first fluid is that derived from external matter, — the chyle; then that into which this is formed, and which is distributed through the system, — the blood; then the various fluids produced from this.

To show the preponderance of the fluid over the solid matter of the body, Blumenbach states that he possesses the entire, but *perfectly dry*, mummy of a Guanche, or aboriginal inhabitant of Teneriffe, presented to him by Sir Joseph Bankes, which, with all its muscles and viscera, weighs but seven pounds and a half.[i]

[h] *Grundriss der Physiologie*, 68.

[i] *Instit. Physiol.* sect. 1. edit. 4. Gottingæ, 1821.

CHAP. III.

GENERAL VIEW OF THE ORGANS, FUNCTIONS, AND POWERS OF THE HUMAN BODY.

The proximate solids are made up into various *organs;* and the operation of an organ is termed its *function.*

While a part is performing its functions, and even while it only remains in a condition fit for the performance of its functions, changes of its constituent particles go on; indeed, many functions are in a great measure but chemical changes. The separation of one portion of matter must occasion the addition of another to be necessary. Hence organs are framed for receiving matter from without, and for changing it variously, so as to fit it to become a portion of the fluids of the body; for distributing it through the body, and rendering it a part of the body; and for the separation and elimination of those particles which in the course of the chemical changes must quit the system. We thus observe organs of reception, assimilation, circulation, nutrition, secretion, and excretion. As individuals last but a limited time, the species is preserved by the generation of new beings from individuals. Organs of generation are therefore framed; but this function is merely circulation, secretion, excretion, and nutrition.

We perceive external objects and circumstances; are conscious of much within ourselves; we think, desire, and exert volition. The organs of these functions are termed the nervous system. It exists in mass, and is also ramified throughout the frame. Impressions upon the extremities of its ramifications, as well as upon these in their course, are conveyed along them to the mass, where they are perceived; and the mandates of the will are conveyed from the mass along the ramifications to fleshy organs of motion, termed muscles; and the influence of emotion is also conveyed from the mass along the ramifications to every part.

The ancients arranged all these functions in four classes: — The *vital*, or those constantly necessary to life, comprising respiration and the action of the heart: the *natural*, or those by which the body is nourished: the *animal*, or those which principally distinguish animals from vegetables, viz. sense, consciousness, desires, thought, volition : and the *genital*.

The functions are now generally arranged in two classes: the *animal*, constituting one peculiar to animals; and the vital and natural, united into another, common to vegetables and animals, under the title of *organic* or *vital*. The generative, relating in their object to the species rather than to the individual, and of but temporary duration, are thrown into a separate and inferior division, but in fact, except the animal passion, are part of the organic.

We owe the revival of this classification, and our knowledge of the characteristics of each class of functions, to Dr. Wilson Philip [a] and Xavier Bichat [b]; although the latter, from having published a work expressly on the subject, has received the whole honour, both in Great Britain and on the Continent.

The *animal* functions prove us feeling, thinking, and willing beings: they are the actions of the senses which receive impressions; of the brain which perceives them, is conscious, desires, reflects, and wills; of the voluntary muscles which execute the will in regard to motion; and of the nerves which are the agents of transmission: the brain is their central organ. The *vital* or *organic* functions are independent of mind, and give us simply the notion of life: they are digestion, circulation, respiration, exhalation, absorption, secretion, nutrition, calorification : the heart is their central organ.

The organs of the animal functions are double and correspondent, there being on each side of the median line of the body either two distinct organs, as the eyes, ears, extremities; or two correspondent halves, as is the case with the brain, spinal marrow, nose, tongue, &c.

[a] *Treatise on Febrile Diseases*, ch. iii. sect. 3. First edition. 1799. *Paper read to the Royal Med. Society of Edinburgh*, 1791 *or* 1792, *and inserted in its Records. Essay on Opium*. 1795. *Edinburgh Med. and Surgical Journal*, July, 1809. p. 301. sq.

[b] *Recherches Physiologiques sur la Vie et la Mort*. 1805.

The organs of the vital or organic functions are in very few instances double, or situated with their centres in the median line and possessed of symmetrical halves; witness the heart, stomach, liver. There are, indeed, two kidneys, but they continually differ in size, figure, and situation: the two lungs are very dissimilar. [c]

Hence Bichat infers, that in the animal functions a harmony of action in each organ, or in each half of the organ, is indispensable to perfection, when both organs or sides act together; and that if such harmony do not occur, it is better for one organ or one half to act alone. This certainly appears true of the eye, and ear, and even of the brain. It certainly does not hold good in the actions of the voluntary muscles, nor in the operations of the brain or spinal marrow in willing those actions. From the duplicity of the organs it also happens that one side may cease to act without detriment to the function of the other; while, in the vital or organic class, no harmony of action is possible, and the derangement of any one part of an organ generally affects the whole of it, — an obstruction in the colon disturbs the functions of all the alimentary canal.

The animal functions experience periodical intermissions — sleep. The organic or vital continue incessantly, suffering merely remissions: — the blood constantly circulates, the perspiratory fluid is constantly secreted, the stomach has no sooner digested one meal than we commit another to it, yet we shall hereafter

[c] As the nerves of one perpendicular half of the body are connected with one half of the brain or spinal marrow, it is not surprising that we often see a loss of motion or of sense, or the reverse, viz. spasms or convulsions, or even an excess of sensibility, in one perpendicular half of the body. But we have examples of ague affecting only one perpendicular half of the body (*Ephemer. Nat. Curios.* and *Mémoires de Montpellier*, 1827): of persons who sweated on one perpendicular half only, (*Ephemer. Nat. Curios.* Dr. Abercrombie on *Diseases of the Brain and Nerves* (the line on the face was distinctly marked), p. 284. Dr. Andral, *Clinique*, vol. i. p. 477.): and of a child that became pale and emaciated in one perpendicular half, while the other remained plump and healthy. (Dr. Falconer, *Memoirs of London Med. Soc.* vol. ix.) Still, as we have paralysis and convulsions also in a horizontal half, so instances are on record of ague affecting a horizontal half (*Journal de Médecine*, t. xxiv. p. 60. January, 1766); and of one horizontal half sweating (Andral, *ib.*): and as we have also examples of paralysis and convulsions affecting a limb only, so ague is said sometimes to have seized but a single limb. (Dr. Macculloch, *on Marsh Fever and Malaria.*)

see that the actions of the heart, lungs, &c., have intervals of remission.

The animal functions are much influenced by habit; the vital or organic are considered by Bichat as removed from its influence. The power of habit over our sensations and voluntary motions is manifest, — the more frequently an object is applied to our organs of sense, the less intense is the sensation produced by it; and the more frequently we perform an act of volition, the more readily is it performed. Yet I think the force of habit equally great over the organic functions. The operation of food and of all descriptions of ingesta is most remarkably modified by habit; through it poisons become comparatively innocuous, and divers bear a long suspension of respiration.

Bichat regards the passions as directly influencing the organic functions only, and springing from the state of the organs of that class. Here he is to me perfectly unintelligible. Vexation indeed disturbs the stomach, and fear augments the quantity of urine; but does not vexation equally and as directly disturb the mind, — confuse the understanding, and occasion heat and pain of the forehead? Are not, in fact, the passions a part of the mind? — a part of the animal functions? They powerfully affect, it is true, the organic or vital functions, but this shows the close connection merely between the two classes of functions.[d]

This connection is conspicuous in respiration, the mechanical part of which belongs to the animal functions, the other to the organic; and in the alimentary functions, in which the food is swallowed and the fæces rejected by volition, and digestion, &c. performed, independently of our influence, by the powers of simple life. So close indeed is this connection, that every organ of the animal class is the seat of organic functions; — in the voluntary muscles, the organs of sense, and even in the brain, circulation, secretion, and absorption are constantly carried on. This connection is likewise apparent in the property of sensibility. In the language of Bichat, there are *animal sensibility and contrac-*

[d] Bordeu, Buffon, Cabanis, and the anatomist Reil, placed the passions in the thoracic and abdominal viscera, &c.; the two first in the diaphragm particularly. Gall has shown the absurdity of these authors in his *Fonct. du Cerveau*, t. ii. p. 93. sqq. We might as well consider the cheeks the seat of the feeling of shame, because in shame we blush. Hippocrates opposed such absurdities in his day. "The heart and præcordia," says he, "feel acutely,' but have not the least intelligence: the *brain* is the cause of all these things." *De Morbo Sacro.*

tility, and *organic sensibility and contractility*, besides the common extensibility of matter, which he terms *extensibilité de tissu*, and common contractility upon the removal of distension, — *contractilité par défaut d'extension*, which, indeed, is greater during life than afterwards.[c] *Animal sensibility* is accompanied by a perception

[c] The following is Bichat's table of the properties of the living body: —

	Classes.	*Genera.*	*Species.*	*Varieties.*	
Properties.	1 Vital	1 Sensibility	1 Animal		
			2 Organic		
		2 Contractility	1 Animal		
			2 Organic	1 Sensible	Such as the motion of the *heart* and *alimentary canal.*
				2 Insensible	Such as the motion of the *capillaries.*
	2 Structural	1 Extensibility			
		2 Contractility			

Although these are the general properties of the living frame, and sensibility, or more properly excitability, is at the bottom of all the other vital or organic properties except the active power of contraction, yet each part has also some peculiarity, altogether inexplicable,—not in the least, I think, to be accounted for on Bichat's supposition of each part possessing a certain *degree* of organic sensibility in relation to its fluids. What causes the vessels of muscle to produce muscle; of bone, bone; of membrane, membrane; what causes the secreting vessels of the liver to form bile, and of the testes semen, we know not. The causes of these circumstances are called by Blumenbach, after Bordeu, *vitæ propriæ;* but it must be carefully remembered, that this expression simply denotes an unknown cause of a fact, and affords no explanation.

Feeling (I use the word for want of another to embrace consciousness and perception) is in the same manner at the bottom of all the mental properties except the active power of willing, but it alone will not explain them. All matter is probably the same; but its *modifications* likewise are so various, that at present we are compelled to speak of distinct kinds of matter.

The operation of agents on the system is analogous. As far as they all affect the living solid, they may be all called stimuli; but they differ in something more than *degree* of stimulus. Each affects particular parts more than others; each affects in a peculiar way; some directly depress life, and many occasion opposite results in different parts; some produce specific diseases, in which the composition of the fluids may be altered; and here occasionally the specific disease produced is contagious.

When organic sensibility is heightened in one part, it sinks in another, and *vice versâ;* unless the change of it should be such as to extend generally, and even then it is still frequently found in the opposite state in some particular part: *v. c.* we notice coldness and paleness of the feet, and heat and fulness of the head, in the mind, as in seeing, hearing, tasting, smelling, feeling: *animal contractility* is excited by the volition of the mind conveyed to the voluntary muscles by means of the nerves. *Organic sensibility* is attended by no perception, and is followed by con-

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together; blisters relieve internal inflammation, and irritate the more difficultly in proportion to the violence of the internal disease. The same phænomena are observable in animal sensibility and in the mind at large: —

> "Tut, man! one fire puts out another's burning,
> One pain is lessen'd by another's anguish;
> Turn giddy, and be holp by backward turning;
> One desperate grief cures with another's languish;
> Take thou some new infection to thy eye,
> And the rank poison of the old will die."
>
> SHAKSPEARE. *Romeo and Juliet*, act i. sc. ii.

The effect of vicissitudes of temperature, and a large number of other pathological phænomena, are principally explicable on the derangement of the balance of excitability, and for the most part, *consequently*, of circulation.

Notwithstanding it is a general law that the effects of an agent diminish the more frequently it is applied, and *vice versâ*, as shown on the one hand, in the large quantities of spirituous liquors which persons at length bear, and on the other by the violent inflammation excited by the application of warmth to parts exposed to intense cold; yet, if a stimulus is applied so energetically as to leave the sensibility heightened, especially if to the point of inflammation, its subsequent power is greatly increased. Immense potations of spirituous liquors may gradually be borne, but if the increase is too great, the sensibility of the stomach may become such that a single glass will prove violently irritating.

The general law, to which the effects of agents, in proportion to their previous application, is referable, appears to be this; — that an agent acts according to the *difference* between its strength and the strength of the former application. Thus, if the right hand be immersed in water of 30°, and the left in water of 50°, and both are removed to water of 70°, the effect of the water at 70° upon the right hand will be greater than upon the left, on account of the difference between 30° and 70° being greater than between 50° and 70°; and this explains the glow of the cold bath, as, during immersion, there is less stimulus, and, on emerging, the temperature of the atmosphere, and the re-admitted blood into the superficial vessels, though stimuli absolutely of the same strength as before immersion, are, *comparatively*, more powerful than what the system experienced during immersion.

The specific action of one agent frequently prevents or destroys that of another: *e. c.* small-pox and measles very rarely occur together; the former disease is frequently prevented for ever by the cow-pock; bark cures the effect of marsh traction totally independent of the will: — the heart is said to feel (physiology has no proper term for the idea, but *excitability* would answer the purpose) the stimulus of the blood, and, without our influence, forthwith contracts; the lacteals to feel the stimulus of the chyle without our knowledge, and they then propel it

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miasmata. It in some cases destroys its own power in future, as is exemplified in those diseases which occur usually but once during life.

These observations on rare and frequent agency may relate to agency in general or by particular agents. A very high or low excitement may influence the effects of all subsequent stimuli; but the rare or frequent application of a particular agent in less intensity may influence its own effects only, as is exemplified in the acquired capability of smoking or taking snuff, while other vapours or powders affect no less than usual.

While moderate excitement is necessary to maintain action and excitability, and excitement by one stimulus, within due limits, augments the effects of another, violent excitement wears out the power, and, very violent, may suddenly destroy life altogether: according to the verses,

Nutritur ventis, ventis extinguitur ignis,
Lenis alit flammas, grandior aura necat.

Dr. John Brown, seizing the undeniable general facts respecting the effect of rare or frequent application upon the power of stimuli, and naming all agents stimuli, founded a system of pathology and practice at once absurd and destructive. (*Elementa Medicinæ.*) Exhaustion, from excess of stimulus, he termed direct debility; torpor, from deficiency of stimulus, indirect debility; and however inflammatory a disease, if it arose from a stimulus, it was to be treated by violent stimuli, to prevent the excitability from falling too low.

In the first place, he abused the word stimulus, by confounding it with the word agent, forgetting what has been just advanced respecting the peculiar properties of every agent, — that some depress, and thus, though agents, are not stimuli; and some affect different parts differently; and some have a specific power upon certain parts and certain diseases, and against other agents.

In the second place, he forgot what has been just said respecting the necessity of a certain degree of excitement to maintain excitability; the effect of one stimulus, within due limits, of increasing the effect of others; and the fact of a stimulus producing so much excitement, that morbid sensibility occurs, far less stimulus than was at first applied causing ten times the effect, and this being reducible only by lessening all stimuli, — the temperature, the quantity of blood, &c., and stimulating distant parts. He forgot, also, the effect of sympathy and specific action.

His error was in keeping in view some general laws, which all know and acknowledge, to the exclusion of others of at least equal importance.

without our assistance.[f] But although we never acquire the least direct voluntary power over the actions of organic contractility,— over the peristaltic motion of the intestines or the contractions of the heart, yet every organ of the organic functions may have its organic sensibility heightened into animal sensibility, as inflammation, for instance, of the pleura and the joints, daily demonstrates; indeed, in some organs of that class of functions, we invariably have sensation; — the stomach is the seat of hunger; in the lungs we experience an uneasy sensation nearly as soon as their air is expelled.

The nerves of the animal functions run to the brain or spinal marrow; those of the organic chiefly to ganglia; but, as might be expected, the two nervous systems have abundant communications.

The animal functions have not only a shorter existence than the organic, from their necessity of alternate repose[g], but they flourish for a shorter duration,—they do not commence till birth, they decline, and, in the natural course of events, terminate, earlier, *v. c.* the organs of sense and the mental faculties fail before the action of the heart and capillaries. But the decay of the animal functions must, in truth, be only the consequence of the decay of the organic, because there are fundamentally in every part organic functions,— circulation, nutrition, &c.; and the perfect performance of these in the organs of the animal functions is indispensable to the perfect performance of the animal functions. Hence the impairment of these organic functions, even to a small extent, must derange or diminish the animal functions, and the decline of the latter is really owing to the decline of the former, although these still remain vigorous enough to appear unimpaired.

[f] There is no proof of feeling. There can be no feeling. We see them act in consequence of the stimulus, and say they feel. The expression is only admissible figuratively, but as all figurative terms in physiology are continually accepted literally, and establish the most absurd notions, especially among the vulgar, it had much better be explained by a mere expression of the fact, by the word *excitement*.

[g] It is said that the heart has the same repose as the brain, the auricles and ventricles acting in succession, and a pause occurring before their action is renewed. The function, however, of the heart as a whole organ, constantly goes on; while that of the brain, at least if it is *only* an organ of the mind, entirely intermits in sound sleep.

We thus find in every living system a class of functions, not in themselves dependent upon mind, as perfect in the vegetable as in the animal, and pervading every part of the system. In animals there further exist certain parts which, when endowed with the common life of other parts, — with the organic properties, — are able to perform peculiar functions which give us the notion of mind: the organ of these functions is termed brain, and, by means of nerves and medullary prolongations, it maintains a correspondence with the whole machine, influenced by and influencing the most distant parts.

The ORGANIC FUNCTIONS depend on LIFE, in the proper acceptation of the word. The word life should be regarded, like the word attraction or repulsion, as merely an expression of a fact. In this point of view it may be as easily defined as any other expression. By LIFE we generally mean the power of organised matter to preserve its particles in such chemical relations as to prevent other chemical relations from inducing disorganisation, or even to increase or decrease by internal appropriation and separation[h]; to produce peculiar matters for its own purposes; to preserve, in some measure, a temperature distinct from that of the surrounding medium; to move certain parts of itself sensibly (as muscles) or insensibly (as the capillaries) independently of mere impulse, attraction, or repulsion: or if not organised (as the fluid which becomes the embryo, the blood,) the power of matter produced by an organised body endowed with the properties above mentioned, to resist the ordinary chemical influences, and even directly form (as the embryotic fluid) an organised system so endowed, or directly become, (as the fibrin, when it is secreted from the blood or blood is effused, becoming vascular, and its new vessels inosculat-

[h] So striking is this, that Stahl and his followers referred their notion of life to this antiseptic property, and while he said, " Life is formally nothing more than the preservation of the body in mixture, corruptible, indeed, but without the occurrence of corruption," Junker said, " What we call life is the opposite of putridity."

Chemical affinities are not destroyed by life, but only so brought to play that decomposition is not their result. Without the operation of chemical affinities the composition of the body could not exist, nor many of its functions, as respiration, secretion, &c., take place. The physical properties of matter are equally indispensable. Cohesion, gravity, hardness, softness, and fluidity are essential, in different parts; elasticity performs an important part in many functions, as in respiration and the rise of the epiglottis; the laws of light and sound are indispensable to the functions of the eye and ear.

ing with those of adjoining parts,) the organised substance of an already formed system so endowed.

That fluids as well as solids are susceptible of life, I cannot doubt. There is no reason why they should not be so, although a person who has not thought upon the subject may be as unable to conceive the circumstance as a West Indian to conceive that water may by cold become solid. It is impossible to deny that the male or female genital fluid, or both, either alone or when united, are alive, because from their union, or from one when influenced by the other, a living being is produced which partakes of the vital qualities of each parent. Accordingly Blumenbach, in his *Commentatio de vi vitali sanguini deneganda*, grants both male and female genital fluids to be alive[i], notwithstanding that he fancies his victory over the defenders of the blood's life so complete, that, like that of the unfortunate Carthaginian Dido, he says, "*in ventos vita recessit.*" It is as easy to conceive the blood to be alive as the genital fluids.[k]

Many facts adduced as arguments of its life are certainly expli-

[i] In universum sane post omnia quæ super hoc argumento sive meditando sive experiundo hactenus elicere licuit, nulli humorum nostri corporis genuina vis vitalis tribuenda videtur, si unice a genitali utriusque sexus latice discesseris, utpote cui jam ante quam uterino cavo exceptus et intime mixtus in fœtus formationem abit, vitales inhærere vires formativas, præter alia paterni vultus in nepotes propagata similitudo, aliaque id genus phænomena haud infitianda demonstrare videntur." *Comment. Soc. Reg. Societ. Gotting.* vol. ix. p. 12.

[k] The doctrine of the life of the blood was maintained by Critias and his sect among the ancients (Aristotle, *De anima*, cap. 2.), Harvey (Exercit. L. *De Generationis ordine*, &c.), Glisson (*De ventriculo et intestinis*), and Albinus. (Blumenbach's *Commentat.* l. c.) I am surprised that Moses should have been adduced by Harvey as authority for this opinion. When he says (*Leviticus*, ch. xvii. 11. 14.), "For the life of the flesh is in the blood,"—"For it is the life of all flesh,"—he can only mean, that, when it is withdrawn, life ceases,—that it is necessary to the life of animals. He also says, (v. 14.) "the blood of it is FOR the life thereof." The construction which would make Moses assert that the blood is alive, involves the absurd assertion that the blood only is alive. Indeed, before the time of Moses, the expression was used to Noah. In *Genesis* (ix. 4.) we read, "Flesh with the life thereof, which is the blood thereof, shall you not eat." The whole of the matter appears to be, that the Jews, like other neighbouring nations, were in the habit of tearing limbs and cutting flesh from living animals, and eating these portions raw. Saul's army after a battle did this. (1 *Samuel*, xiv. 32, 33.) To prevent this horrid cruelty, they were forbidden to eat flesh before the animal had been drained of its blood, and thus deprived of life; and what is, in our own version of the Bible, rendered, "flesh with the life thereof, which is the blood

cable without such a supposition. Its freedom from putrefaction while circulating may be owing to the constant renovation of its particles; for the thinness of hybernating animals at the end of their torpid season shows it has received accessions even in them, and this from the absorption of fat. Its inability to coagulate after death from arsenic, opium, and some other narcotics, and from lightning and electricity (though Sir C. Scudamore found it to coagulate as usual in the latter case), from hard running, anger, or a blow on the stomach, all three of which deprive the muscles of their usual stiffness, may depend upon chemical changes. The admixture of opium with the blood has been said to prevent its coagulation, and this by destroying its life. But Sir C. Scudamore found that the admixture of prussic acid and belladonna, both strong poisons, has no such effect, and that many mere salts, as common salt, weaken or prevent its coagulation, and these are not likely to kill it, but to act chemically. Its accelerated coagulation by means of heat, when frozen by cold, and some other circumstances, and the reverse, were believed to depend upon an affection of its vitality, but are, perhaps, referable to some chemical effect. Its earlier putridity when drawn from young than from old persons may arise from its inferior qualities. Parts die if deprived of a supply of blood; yet, though necessary as a material and agent to maintain the life of parts, it is not, therefore, necessarily itself alive. But the circumstance of its freezing more readily, like eggs, frogs, snails, &c., when once previously frozen (which change may be supposed to have exhausted its powers [l]), is, if really the case, an argument in favour of its life, as these are certainly endowed with life. The organisation of extravasated blood [m], and the inosculation of new vessels with those of surrounding parts, shows [n] that the solidified lymph is now endowed with

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thereof," is said to be rendered by the best interpreters, " flesh or members torn from living animals having the blood in them." See Bruce, *Travels to discover the Source of the Nile*, vol. iii. p. 297.

[l] Corrie, *on the Vitality of the Blood*, p. 45.

[m] J. Hunter, *Treatise on the Blood, &c.* p. i. ch. 1.

[n] Dr. John Thomson believes, that, when blood has been effused between divided surfaces, its coagulum is absorbed, and *secreted* lymph only coagulates and becomes vascular. *Lectures on Inflammation*, p. 214. Yet at page 216. he does not deny the occurrence.

life; and one may more easily believe it to have been alive in the mass of blood, than that it should have acquired vitality after its effusion. Indeed Sir Everard Home declares that a coagulum of blood becomes vascular out of the body, and may be injected[o]; but if the vessels are formed by the mere extrication of carbonic acid gas, as he contends, their mere formation is no proof of life.

John Hunter believes that the chyle is alive, and some that vivification commences in the stomach; and Albinus grants life even to the excrement. But the excretions must be regarded as dead matter, useless and foreign to the system, and they all run with the greatest rapidity into decomposition. In operating for retention of urine, the surgeon finds this fluid abominably fœtid; the fæces become so when not discharged in due time; and the neglect of washing the surface is the source of filth and disease.

The essential nature of life is an impenetrable mystery, and no more a subject for philosophical enquiry than the essential nature of attraction or of heat. To attempt explaining the phenomena of life by a vital fluid is only increasing the intricacy of the subject by an unfounded *hypothesis*, and always reminds me of Mr. Dugald Stewart's remark,—"That there is even some reason for doubting, from the crude speculations on medical and chemical subjects which are daily offered to the public, whether it (the proper mode of studying nature) be yet understood so completely as is commonly imagined, and whether a fuller illustration of the rules of philosophising, than Bacon or his followers have given, might not be useful even to physical enquirers."[p] We see matter in a certain state possessed of a certain power which we term life, and the object of physiology is merely to observe its effects, just as it is the object of chemistry to observe the circumstances of the affinity of different bodies and of physics to observe other phenomena of matter, without vainly speculating on the essence of affinity or the essence of matter, to comprehend which our faculties are, in their nature, incompetent. By attributing life, the power of attraction, &c. to subtle and mobile fluids, we not only do not advance a single step, for we have still to explain what these fluids are, and how *they* obtain *their* powers, just as we had before in regard to common matter; but we make the addi-

[o] *Phil. Trans.* vol. cviii. p. 188. sq.

[p] *Elements of the Philosophy of the Human Mind*, vol. i. p. 8.

tional mysteries of their being united with ordinary matter, and so united that life appears a power possessed by *it*. The editors of a medical review have in vain searched John Hunter's works for such an *hypothesis*[q], and Mr. Lawrence has had no better success[r], so that I apprehend his meaning has been misunderstood by those who constitute him its patron.[s] Granting for a moment that *life* depends upon a peculiar, fine fluid, we have still to account for *mind*, because life is not mind, — a cabbage is as much gifted with life as the wisest man. Yet those whose faith makes life a subtle fluid strangely imagine that the doctrine of a soul is thereby advanced. The life of a brute requires a subtle fluid as much as the life of a man, and of a cabbage as much as the life of a brute.

We have reason to believe that life never originates, but began at the creation, and is communicated to assimilated matter, and propagated from parent to offspring. It is the property of organised systems, producing various effects by various kinds of organisation, but is not quite peculiar to organised matter, because capable of being possessed by matter in a fluid state.[t]

[q] *Annals of Medicine and Surgery*, 1817, p. 373. In the *Treatise on the Blood*, (p. 89. sq.) John Hunter says, " Life is a *property* (not a subtle fluid) we do not understand." This property he conceives to reside in a certain matter similar to the materials of the brain ; diffused through the body and even contained in the blood. " The brain," he adds, " is a mass of this matter, not diffused through any thing, for the purpose of that thing, but constituting *an organ* in itself." This *materia vitæ* is, therefore, not *subtle*, but pretty solid, and no other than medullary matter ; and Vauquelin says he has discovered a fatty matter in the blood, and which M. Chevreuil thinks he proves to be the same as the substance of the brain and nerves. But the subtle-fluidists would not tolerate *gross fatty* matter, and J. Hunter calls life a *property*.

[r] *Lectures on the Physiology, Zoology, and Natural History of Man*, p. 84.

[s] J. Abernethy, *Lectures delivered before the Royal College of Surgeons*. 1814.

[t] As the fluids which form the embryo must be endowed with life, organisation cannot be the cause of life ; but in truth, organisation is the effect of life, although when produced it becomes an instrument of life. The erroneousness of the French doctrine, that " life is the result of organisation," was refuted in the *Annals of Medicine and Surgery*. (1816, Sept. pp. 346. 386.) The error appears to have arisen in some measure from the want of definition, — the word life being used sometimes properly for the power, sometimes improperly for the result. Even if the result of life, — the functions of a part, should be called its life, life could not be said to be the result of organisation, but of a power to which organisation is an instrument. The Greeks had distinct appellations for the cause and the result ; the former they termed ψυχὴ ; the latter, ζωὴ.

The ANIMAL FUNCTIONS demonstrate MIND. This is seated in the brain, to which the spinal marrow, nerves, and voluntary muscles are subservient. MIND is the functional power of the living brain. As I cannot conceive *life* any more than the power of attraction unless possessed by matter, so I cannot conceive *mind* unless possessed by a brain, or by some nervous organ, whatever name we may choose to give it, endowed with life. I speak of terrestrial or animal mind; with angelic and divine nature we have nothing to do, and of them we know, in the same respects, nothing. To call the human mind positively a ray of the divinity, (*Divinæ particula auræ* [u], *Ex ipso Deo decerptus*, *Ex universa mente delibatus* [x],) appears to me absolute nonsense. Brutes are as really endowed with mind, — with a consciousness of personality, with feelings, desires, and will, — as man. [y] Every child is conscious that it thinks with its head, and common language designates this part as the seat of mind. [z] Observation shows that superiority of mind in the animal creation is exactly commensurate with superiority of brain [a]; that activity of mind

[u] Horace.

[x] Cicero, *De Senectute et Quæst. Tuscul.*

[y] See Gall, l. c. t. 1. p. 56. sqq. Aristotle no sooner asserts that a share of divinity is bestowed on man " only of all animals," than he is obliged to retract, and say, " or most of all animals,"—ἢ μάλιστα παντων. *De part. animal.* l. ii. c. 10.

[z] A stupid person is honoured with the expressions numb-*scull*, thick-*head*, addle-*pated*, shallow-*pated*, badly furnished in the *upper story;* a clever person with strong-*headed*, long-*headed*, having plenty of *brains;* a madman is said to be wrong in the *head*, touched in the *noddle*, &c. A person whose memory or power of attention is impaired, says he has no *head*, &c. When a catarrh chiefly affects the head, we complain of stupidity, because " we have such a cold *in the head*," &c. A man is always said to have an idea in his *head*.

[a] " The same progression which exists in the gradual perfection of animal organisation, as far as regards vegetable life only, is observed in the gradual perfection of the nervous system, and of animal life which depends upon it. Comparative anatomy has followed the gradual perfection of animals, from the most simple absorbent vessels to the most complicated apparatus of mastication, deglutition, and digestion, — to the most perfect circulation. With every fresh viscus, every fresh apparatus for sensation, is discovered a fresh function, and this function is more complicated in proportion as the organisation of the viscus or apparatus of sensation is more perfect. The stomach, kidneys, lungs, heart, eyes, ears, are the more complicated as their functions become so.

" The same gradation may be demonstrated in the structure of the brains of the different species. I have demonstrated in the preceding chapter, that the existence of each moral quality and intellectual faculty, depends solely upon the and of brain are coequal; and that, as long as the brain is endowed with life, and remains uninjured, it, like all other organs, can perform its functions, and mind continues; but, as in all

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presence of certain determinate cerebral parts, and not upon the whole mass of brain. It follows, that the number of the faculties is in direct proportion to the integrant parts of the brain. In insects, fish, and amphibia, the nervous mass contained in the cerebral reservoir, is still divided into several distinct masses. The greater part of these are not integrant parts of the brain, properly so called; they are ganglia, from which arise the nerves of smell, hearing, sight, &c. The two hemispheres, properly so called, are placed behind the two ganglia of the olfactory nerves, and are the more complicated as the industrial instincts are more numerous; the cerebellum in these animals generally forms a hollow pouch, sometimes placed horizontally, sometimes folded together.

"In birds, the two hemispheres are already more considerable, although distinct convolutions cannot be discerned. The cerebellum still consists merely of its middle or fundamental part; but already appears composed of many rings placed side by side.

"In the small mammalia, the shrew-mouse, mouse, rat, squirrel, weasel, &c. convolutions are not yet discoverable. But as they are already distinctly found in other larger rodentia, the beaver, kangaroo, &c., we may suppose that they equally exist in them.

"In the larger mammalia, the cat, polecat, marten, fox, dog, ape, the convolutions are more distinct and numerous, but their form varies according to the species.

"In the dolphin, elephant, and man, they are more numerous and deep than in the beaver, kangaroo, cat, &c., and their form and direction vary completely according to the species.

"In all the mammalia, the cerebellum possesses, besides the middle or fundamental part, two lateral parts, which are more or less complicated, according to the species; and as the *soi-disant* pons varolii, or the *soi-disant* cerebral ganglia, *i. e.* the transverse layers of nervous bands, are only the commissure or junction of the lateral parts of the cerebellum, they are found in all the mammalia, and in none of the ovipara.

"The number of the integral parts, or of the convolutions of the brain, varies equally in the different species of mammalia; in some, the anterior lobes of the hemispheres are larger or more elevated; in others, again, the inferior parts of the anterior lobes are nearly wanting. The middle lobes, and the other convolutions, present similar varieties.

"In this way, the integrant parts of the brain augment in number and developement, as we pass from a less perfec to a more perfect animal, till we arrive at the brain of man, who, in the anterior-superior, and in the superior region of the frontal bone, possesses several parts of which other animals are deprived, and by means of which he is endowed with the most eminent qualities and faculties, with reason, and the feeling of religion and the existence of God." Gall, other organs, when its life ceases, its power to perform its function ceases, and the mind ceases: when disease or mechanical injury affects it, the mind is affected,—inflammation of the stomach causes vomiting, of the brain delirium, a blow upon the loins suppression or alteration of the urine, a blow upon the head stuns; if originally constituted defective, the mind is defective [c]; if fully de-

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l. c. t. ii. p. 364. sqq. " Some pretend to discover a striking resemblance between the brain of an orang-utan and that of man. But, in the first place, the difference of their volume is as five to one; their convolutions differ considerably in number and structure; the anterior lobes, especially, are contracted into a cone, flattened above, hollow below, &c.; and the difference is still more remarkable in other simiæ." t. vi. p. 298.

[c] See Gall, l. c. t. i. p. 196. sqq., and t. ii. p. 322. sqq. " Willis has described the brain of a young man imbecile from birth; its volume is scarcely $\frac{1}{5}$th part of that of an ordinary human brain. M. Bonn, professor at Amsterdam, has two little crania of idiots, and the brain of an imbecile who attained his twenty-fifth year, and was so stupid, that he was shown for money as an African savage," &c. " I have observed heads equally small in many living idiots from birth. All these crania and heads are 13 or 14 inches in circumference, and 11 or 12 inches from the root of the nose to the foramen occipitale." — " With from 14 to 17 inches in circumference; and about 10 or 12 from the root of the nose to the foramen occipitale, we have more or less stupidity, a more or less complete incapacity to fix the attention upon one object; uncertain and transitory feelings and passions; confusion of ideas," &c.—" Heads of 18 or 18½ inches in circumference are still small, although they permit a regular exercise of the faculties; they possess but a sad mediocrity of talent, a spirit of servile imitation, &c.; an extreme deficiency of seizing the relation between cause and effect; a want of self-government, and often few desires. Still some qualities or faculties may be considerable, because particular organs may be greatly developed, forming a striking contrast with the mediocrity of the rest. But as we approach larger brains, we see intellectual faculties of greater magnitude, till we arrive at heads 21 or 22 inches in circumference, — the dimensions at which men obtain the height of intelligence." Gall means French inches, which are about $\frac{1}{18}$ longer than the English.

" The dimensions of the brain," says Dr. Magendie, " are proportioned to those of the head. In this respect there is a great difference in individuals. The volume of the brain is generally in direct proportion to the capacity of the mind."—" It is rarely found that a man distinguished by his mental faculties has not a large head."— *Précis de Physiologie*, t. i. p. 184.

Dr. Marshall, an anatomical lecturer in London from two-and-forty to six-and-twenty years ago, taught that the brain was the organ of mind, its original defective conformation a source of idiocy, its disease the cause of insanity; and gave many dissections of maniacs, and an excellent sketch of the varieties of the disease. *Morbid Anatomy of the Brain, &c. collected from the papers of the late Andrew Marshall*, M.D., by S. Sawrey, London, 1815.

veloped, and properly acted on, the mind is vigorous: accordingly, as it varies with age, in quality and bulk, is the mind also varied,— the mind of the child is weak and very excitable, of the adult vigorous and firm, and of the old man weak and dull, exactly like the body[d]; and the character of the mind of an individual agrees

[d] If of children it is said,

—— "Inter se quas pro levibus noxiis iras gerunt?
Quapropter? quia enim qui eos gubernat animus, infirmum gerunt."
Terence, *Hecyra*.

The old man,—"Res omnes timide gelideque ministrat,
Dilator, spe longus, iners—" Horace, *Ars Poetica*.

Or, in the plainer language of Shakspeare, "Old men have grey beards, their faces are wrinkled, their eyes purging thick amber and plum-tree gum, and they have a *plentiful lack of wit*, together with most weak hams."
Hamlet, act 2. sc. 2.

Mr. Dugald Stewart allows that "In the case of old men, it is generally found that a decline of the faculties keeps pace with the decay of bodily health and vigour. The few exceptions that occur to the universality of this fact, only prove that there are some diseases fatal to life, which do not injure those parts of the body with which the intellectual operations are more immediately connected."—*Outlines of Moral Philosophy*, p. 233.

"Præterea gigni pariter cum corpore, et una
Crescere sentimus, pariterque senescere, mentem." Lucretius, lib. i.

"In new-born children, it is difficult to discern, without maceration in spirits of wine, any traces of fibres in the great collections of grey, reddish substances, or the great cerebral ganglia, which supply, reinforce, and perfect, or which, according to the opinion of others, give activity to, the hemispheres. The nervous fibres are more visible in the middle and posterior lobes than in the anterior. The fibrous structure of the white substance of the cerebellum also becomes apparent gradually, and in proportion to its developement. All the nervous fibres are at this period still so involved in the more or less reddish and gelatinous substance, and in blood-vessels, that all the brain looks like a nervous pulp or jelly.

"The only functions of the infant, at this age, are very imperfect, and are those of the five senses, of voluntary motion, hunger, the sensation of being comfortable or uncomfortable, and the want of sleep.

"After some months, the parts of the brain situated near the anterior-superior region of the forehead, grow more rapidly than the other parts. The forehead, from being flat, becomes prominent, and the child begins to fix its attention upon external objects, to compare, and form abstract ideas,—to generalise.

"The whole brain is developed in succession, until, at the age of from twenty to forty, it has attained its full growth relatively to each individual. The cerebellum, likewise, which is smaller than the cerebrum in proportion as the subject is with the character of his body, being equally excitable, languid, or torpid, evidently because the brain is of the same character as the rest of the body to which it belongs, — the female mind exceeds the male in excitability as much as her body[e]; the qualities of the mind are also hereditary[f], which they could not be, unless they were, like our other qualities, corporeal conditions; and the mind is often disordered upon the disappearance of a bodily complaint, just as other organs, besides the brain, are affected under similar circumstances, — the retrocession of an eruption may affect the lungs, causing asthma; the bowels, causing enteritis; or the brain, causing insanity, — phthisis and insanity sometimes alter-

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younger, is developed and perfectly formed towards the age of from eighteen to twenty. The youth, the young man, and the young girl, take an interest in each other; and the talents and inclinations are exercised and perfected till they obtain maturity. From thirty or forty years of age, the cerebrum and cerebellum remain nearly stationary till the fiftieth or seventieth year, according to individual constitution. The same is the case with the moral and intellectual powers. Certain parts of the brain, however, especially those in the anterior-inferior region of the forehead, have at this time already begun to diminish; the memory is less faithful, and the imagination less ardent, and hint to us the approach of old age, and the decline of our faculties.

"At length all the cerebral mass gradually loses its nervous turgescence; it diminishes, wastes, shrinks ('the convolutions lie farther from each other;' t. i. p. 192.); the consistence of its two substances undergoes alteration. The moral and intellectual powers sink in proportion; the inclinations, the talents disappear, the affairs of the world assume a gloomy aspect, the past only is considered good; and, at the age of decrepitude, there remains only imbecility, the weakness of a second childhood." Gall, l. c. t. ii. p. 156. sqq.; also t. iii. p. 28. sqq. Dr. Magendie allows that "the brain is almost liquid in the fœtus, firmer in infancy, and still more so in manhood" (*Précis de Physiologie*); that above the age of seventy, the weight of the brain is on the average $\frac{1}{15}$th less than in the prime of life; and that the convolutions are then often distant half an inch from each other, and their surface very distant from the cranium, as Cotugno had observed. *Journ. de Physiol.* t. vii. p. 5. 87.

[e] "Mulieres sunt, ferme ut pueri, levi sententia." — Terence, *Hecyra*.

[f] "Parentibus liberi similes sunt non vultum modo et corporis formam, sed animi indolem, et virtutes, et vitia. — Claudia gens diu Romæ floruit impigra, ferox, superba: eadem illachrymabilem Tiberium, tristissimum tyrannum produxit: tandem in immanem Caligulam et Claudium, et Agrippinam, ipsumque demum Neronem, post sexcentos annos desitura." — Gregory, *Conspectus Medicinæ Theoreticæ*. So true is the verse

"Et patrum in natos abeunt, cum semine, mores."

nate with each other, just like affections of other organs; the laws of the mind are precisely those of the functions of all other organs, — a certain degree of excitement strengthens it; too much exhausts it; physical agents affect it, and some specifically, as is the case with other functions, for example, narcotics. The argument of Bishop Butler, that the soul is immortal and independent of matter, because in fatal diseases the mind often remains vigorous to the last[g], is perfectly groundless; for any function will remain vigorous to the last, if the organ which performs it is not the seat of the disease, nor much connected by sympathy, or in other modes, with the organ which is the seat of the disease — the stomach often calls regularly for food, and digests it vigorously, while the lungs are almost completely consumed by ulceration. All the cases that are adduced to prove the little dependence of the mind upon the brain, are adduced in opposition to the myriads of others that daily occur in the usual course of nature, and are evidently regarded as extraordinary by those who bring them forward. An exact parallel to each may be found in the affections of every other organ, and each admits of so easy an explanation, that it may be always truly said, " Exceptio probat regulam."[h]

[g] *The Analogy of Religion, natural and revealed, to the Constitution and Course of Nature.* By Joseph Butler, LL.D. Lord Bishop of Durham, p. 33.

[h] I will not insult the understanding of my readers by showing that we have no authentic instance of the real absence of brain in the cranium of a being possessed of a mind. The records of medicine no less teem with wonders than those of theology. The miracles of the Fathers and of the Romish Church may be matched by cases not only of mind without brain, or some similar organ, but of human impregnation without males, or by males without testes, and of human fœtuses nourished without communication with the mother.

In most cases where the mind is *said* to have been vigorous when the state of the body at large, or of the brain alone, rendered the perfect performance of the cerebral functions improbable in the eyes of the relaters, I believe the mental power has been greatly over-rated, — that, because the individual merely talked collectedly, he was imagined sufficient for the exertions of his best health.

The part of the brain affected by disease may have been one whose function is not intellectual, but merely relating to the feelings, or may have related to intellectual faculties whose state was not noticed by the narrators. In truth, the narrators give us no satisfactory account of the feelings and intellectual powers of the patients, nor of the exact portions of the brain affected; nor could they, being unacquainted with phrenology; and they also forget that the cerebral organs are all double. (See Gall, l. c. t. ii. 188. sqq., 246. sqq.; and a paper by Dr. Andrew

I have placed the preeeding arguments alone, but to them may be subjoined another equally demonstrative as any, — that the stength of the various intellectual powers and inelinations accords with the size of the various parts of the brain; that exactly as the various parts of the brain are suecessively developed is the character developed, and as they shrink with age does the character again change.

In contending that the mind is a power of the living brain, and the exercise of it the functions of that organ, I contend for merely a physieal fact; and no Christian who has just conceptions of the Author of Nature will hesitate to look boldly at Nature as she is, lest he should discover facts opposite to the pronunciations of his revelation; for the word and the works of the Almighty cannot

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Combe, on the effects of injuries of the brain upon the manifestation of the mind, in the *Transactions of the Phrenological Society*, Edinb. 1824.)

If after insanity no trace of disease is sometimes discoverable in the brain, let us remember that the same is sometimes the case after epilepsy and various undoubted diseases of the brain, and sometimes with respect to the stomach after chronic dyspepsia. Diseases may be functional only. Nay, when our senses are not nice enough to discover structural affection of the brain in insanity, &c. we have generally strong presumptive evidence of its affection, in the thickening or excessive secretions of its membranes,— points more easily ascertained than equal changes in the delicate texture of the brain.

Those who thus attempt to prove the *substantial distinctness* of the mind and brain, forget that their facts, or rather arguments, are equally strong against what they all admit, — the necessary *connection* of the mind and brain in this life; and are therefore grounded on what, if true, were violations of the course of nature.

There is a passage in Hippocrates, *de Morbo Sacro*, well worth quoting: — "Men ought to know, that from the *brain only* proceed pleasure and joy, and laughter and sport, as well as griefs, anxieties, sorrows, and weeping. By it we are wise especially, and understand, and see, and hear, and appreciate what is base and honourable, good and bad, pleasant and unpleasant, distinguishing them partly by habit, partly by their utility. By it we distinguish what is pleasurable, and what disagreeable, according to circumstances; and, by it, the same things do not please us under all circumstances. By it we are insane and delirious; experience terrors and fears, partly by night, partly by day; and sleeplessness, and ill-timed errors, and groundless cares; do not recognise those who are with us; lose our habits, and forget our experience. And all this we suffer from the brain if it is not healthy, &c.: wherefore I say, that the brain is the messenger and interpreter of intelligence and wisdom. But the *præcordia* have obtained the name of φρένες among the Greeks, by custom, not from fact and nature; and I know not what property they have of knowing and understanding, except that in sudden and great joy or sorrow they leap," &c.

contradict each other. Bacon accordingly, in a very memorable part of his writings, directs the physical enquirer to be uninfluenced by religious opinions[i], as the more independently truth is pursued the sooner will it be gained, and the sooner will the real meaning of a divine statement of natural things, and the conformity of this to physical fact, be established.

The assertion, however, that the mind is a power of the living brain, is not an assertion that is material; for a power or property of matter cannot be matter.

Neither is it an assertion that this power cannot be a something immortal, subtle, immaterial, diffused through and connected with the brain. A physical enquirer has to do with only what he observes. He finds this power, but attempts not to explain it. He simply says the living brain has this power, medullary matter though it be. Seeing that the brain thinks, and feels, and wills, as clearly as that the liver has the power of producing bile, and does produce it, and a salt the power of assuming a certain form, and does crystallise, he leaves others at liberty to fancy an hypothesis of its power being a subtle, immaterial, immortal substance, exactly as they fancy life to be a subtle fluid, or, perhaps, though very extraordinarily, the same subtle fluid (if subtlety is immateriality and immortality)[k], elucidating the subject

[i] Si quis animum diligentius advertat, non minus periculi naturali philosophiæ ex istiusmodi fallaci in iniquo fœdere, quam ex apertis inimicitiis imminere. Tali enim fœdere et societate accepta, in philosophia tantum comprehendi, aucta autem, vel audita, vel in melius mutata, etiam severius et pertinacius excludi. Denique versus incrementa et novas veluti oras et regiones philosophiæ, omnia ex parte religionis, pravarum suspicionum et impotentis fastidii plena esse. Alios siquidem simplicius subvereri, ne forte altior in naturam inquisitio ultra datum et concessum sobrietatis terminum penetret, &c. &c. Quare satis constabat in hujusmodi opinionibus multum infirmitatis, quin et invidiæ et fermenti non parum subesse," &c. — *Cogitata et Visa,* vol. ix. p. 167. 8vo edition. In the same paragraph he remarks, with regret, that no writers are more popular than those who pompously set forth the union of divinity and philosophy, *i. e.* faith and sense, as if it were not illegitimate. " Haud alias opiniones et disputationes magis secundis ventis ferri reperies, quam eorum, qui, theologiæ et philosophiæ conjugium, veluti legitimum, multa pompa et solemnitate celebrant, et grata rerum varietate animos hominum permulcentes, interim divina et humana inauspicato permiscent."

[k] The hypothesis of a subtle mobile fluid is downright materialism — the doctrine of Lucretius.

—— " Quoniam est animi natura reperta
Mobilis egregie, perquam constare necesse est
Corporibus parvis et lævibus atque *rotundis.*" Lib. iii. 204.

no more than in the case of life, and equally increasing the number of its difficulties [i]; as though we were not *created* beings,

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Bacon complained (l. c.) that the first attempts to explain thunder and tempests were accused of impiety by religious persons, who thought that religion demanded these phænomena to be referred to the immediate operation of the Deity. The lovers of subtle fluids and spirits, conversely and as strangely, think religion served by interposing a subtle fluid between common matter and the Deity. Van Helmont was remarkably fortunate, for, after severe meditation, he fell into an intellectual vision, and saw his own soul: "Magna mox quies me invasit, et incidi in somnium intellectuale satisque memorabile." It was very small, and had no organs of generation: "Vidi enim animam meam satis exiguam, specie humana, sexûs tamen discrimine liberam."—*Ortus Medicinæ,* Confessio auctoris, p. 13. He gave the soul, however, a close and dirty dwelling, for he placed it, not in the pineal gland, but in the stomach.

[i] Locke (*Second Reply to the Bishop of Worcester,* p. 477. 8vo edition) in disparaging *philosophical* reasons for the immortality of the soul, says,

"Dr. Cudworth affirms that there was never any of the ancients before Christianity that held the soul's future permanency after death (*i. e.* from its inherent immortality), who did not likewise assert its pre-existence." If we *necessarily* shall exist *to* all eternity, we then must have existed *from* all eternity; yet we are not aware of having been alive before our brains. Sterne's fine ridicule of the absurdities introduced by this hypothesis of a soul, and that independent of the brain, into the Romish church, is well known. A great French man-midwife acquaints us that he baptised a little abortion of the magnitude of a skinned mouse; and on another occasion, when a woman was miscarrying in her fourth month, and the child's posteriors presented, that he sprinkled water upon them and baptized them, in case the little thing should turn out alive. (De la Motte, *Traité complet des Accouchemens,* p. 243. 246.) Dr. Fodéré in his noted *Médecine Légale,* 1813, (vol. ii. p. 62.) gravely suggests that baptism may always be administered by a squirt, after the membranes are pierced,— "Quant au baptême, il me semble qu'il sera toujours facile de l'administrer, après avoir percé les membranes, par le moyen d'un seringue à injection." A good idea of what follows in its train may be collected from Dante's tiresome account of the introduction of the soul into the body, beginning, "Sangue perfetto che mai non si beve," &c.—*Purgatorio,* canto xxv. It is one parent of necromancy, of the belief in ghosts, and of all the popish "trumpery" respecting purgatory and the worship of dead people called saints, of the opinions held by many respecting our occupations between death and doomsday, as if a future state began before; and old writers sicken one with their notions about the period at which the soul enters the body, when it first existed, how it was engaged before it united with the body, and how it employs itself after its separation till the day of judgment, &c. "Hierom, Austin, and other fathers of the church, hold that the soul is immortal, created of nothing, and so infused into the child or embryo in his mother's womb six months after the conception; some say at three days, some six weeks, others otherwise."—Burton's *Anatomy of Melancholy,* p. 1. s. 1. m. 2. subs. 9. Where or not altogether ignorant what matter is, or of what it is capable and incapable; as though matter exhibited nothing but extension, impenetrability, attraction, and inertness; and as though an Almighty could not, if it seemed good to him, have endowed it, as he most evidently has, with the superaddition of life, and even of feeling and will.[m]

Nor does this assertion imply that the resurrection from the dead is impossible, or even improbable. The physical enquirer, finding the mind a power of the brain, and abstaining from hypothesis, must conclude that, in the present order of things, when the brain ceases to live the power necessarily ceases,—that, in the language of scripture, Dust we are, and unto dust we all return,—that our being is utterly extinguished, and we go back to the insensibility of the earth whence we were taken.[n] Our

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the depôt of souls is; how they learn when a youth has impregnated an ovarian vesicle, and how they fly to and get into it; how it happens that the qualities of the soul correspond with the brain, and are as hereditary as those of the body; whether this depends upon souls varying, and, if so, how a soul finds a body just corresponding to itself; or upon the soul being obliged to conform to the character of the brain, and thus suffering by the brain's defects, we are not satisfactorily informed.

[m] "All the difficulties that are raised against the thinking of matter, from our ignorance or narrow conceptions, stand not at all in the way of the power of God, if he pleases to ordain it so." The faculties of brutes prove, "either that God can and doth give to some parcels of matter a power of perception and thinking, or that all animals have immaterial and consequently immortal souls as well as men; and to say that fleas and mites, &c. have immortal souls as well as men, will possibly be looked on as going a great way to serve an hypothesis."—Locke, *Second Reply to the Bishop of Worcester*, p. 466. 8vo edit.

"Si quelqu'un démontreroit jamais que l'âme est matérielle," says the pious and benevolent Bonnet, "loin de s'en alarmer, il faudroit admirer la puissance qui auroit donné à la matière la capacité de penser."

"In the ordinary derivation of plants and animals," says Paley, "from one another, a *particle*, in many cases minuter than all assignable, all conceivable dimensions; an aura, an effluvium, an infinitesimal; determines the organisation of a future body: does no less than fix, whether that which is about to be produced shall be a vegetable, a merely sentient, or a RATIONAL *being*; an oak, a frog, or a *philosopher*; makes all these differences; gives to the future body its qualities, and nature, and species. And this *particle*, from which *springs*, and by which is determined, a whole future nature, itself *proceeds* from, and owes its constitution to, a prior body," &c. — *Natural Theology*, conclusion, p. 591.

[n] *Miscellaneous Tracts, &c.* by Richard Watson, D.D. F.R.S. Lord Bishop of Llandaff. Sermon iii. p. 399, sq.

consciousness of personality can afford no reason for imagining ourselves immortal and distinct from earth, more than brutes; for this the fly possesses equally with the philosopher about whose head it buzzes.[o] The moral government of the world, the sublime reach of our acuteness, the great improveableness of our characters, —

> " —— this pleasing hope, this fond desire,
> This longing after immortality,
> —— this secret dread and inward horror
> Of falling into nought,"[p]

have been thought to completely harmonise with a life hereafter, but certainly fall so short of proof as to have left the wisest of antiquity, — Solomon, Socrates, Cicero, &c. — in uncertainty[q], when they saw how death reduces us to our pristine elements. The hope of immortality inspired by such reflections, assisted by the desire of explaining every thing in some way or other, first, I apprehend, made men attempt to find, in the imagined ethereal essence of the soul, a reason for our not totally perishing as our senses would lead us to suppose. But, because we refuse to listen to a mere hypothesis respecting spirit, we are not *necessarily* to deny the resurrection. For if a divine revelation pronounce that there shall be *another order of things* in which the mind shall exist again, we ought firmly to believe it, because neither our experience nor our reason can inform us what will be hereafter, and we must be senseless to start objections on a point beyond the penetration of our faculties.[r] — The scripture so pronounces,

[o] Heathens have, very consistently with this reason for immortality, given it to the fancied souls of brutes: Ulysses is made by Homer to behold the shade of Orion —

> Θῆρας ὁμοῦ εἰλεῦντα, κατ' ἀσφοδελὸν λειμῶνα
> Τοὺς αὐτὸς κατέπεφνεν ἐν οἰοπόλοισιν ὄρεσσι. Odyss. Λ. 571.

Dr. Thomas Brown believed, " that the *metaphysical* ARGUMENT which proves the immortality of man, extends with equal force to the other orders of earthly existence." *Memoir of Thomas Brown*, M. D., by the Rev. David Welsh. 1828, p. xxii.

And " Bonnet promised brutes immortality."

[p] Addison, *Cato*. See a full enumeration in Mr. Dugald Stewart's *Outlines*, &c. p. 235. sq.

[q] Bishop Watson, l. c. Sermon vi. p. 504. sq.

[r] " Nor can we be obliged, where we have the clear and evident sentence of reason, to quit it for the contrary opinion, under a pretence that it is a matter of faith, which can have no authority against the plain dictates of reason. But

—not that we are naturally immortal, but that "in Adam (by nature) all die[s], —have our being utterly extinguished[t], and in another order of things,—when the fashion of this world shall have passed away and time shall be no more, that in Christ (by the free, additional, gift of God, granted through the obedience of Christ, but, consequently, *by a miracle*, not by our nature[u])—we shall all again be made alive. St. Paul declares the resurrec-

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there are many things wherein we have very imperfect notions, or none at all; and other things, of whose past, present, or future existence, by the actual use of our faculties, *we can have no knowledge:* these, as being beyond the discovery of our natural faculties, and above reason, are, when revealed, the proper matter of faith. Thus, that part of the angels rebelled against God, and thereby lost their first happy state, and that *the dead shall rise and live again:* these and the like, being beyond the discovery of reason, are purely matters of faith, with which *reason has nothing directly to do.*" — Locke, *Essay on Human Understanding*, iv. ch. 18.

Reason's province is only to examine the proofs of the authenticity of a revelation, and faith should thus be founded on reason. But how few of the human race ever think, or are even capable, of carefully examining them! And of those who do examine them, how few do not commence the examination with their minds unconsciously half made up! And yet the greater number look down with a self-complacent and uncharitable feeling upon even good men, whose opinions differ in any respect from their own; forgetting that good conduct is the only test of goodness, — that grapes cannot come from thorns, nor figs from thistles.

The question of the authenticity of Scripture is altogether foreign to this work.

[s] Bishop Watson, *Apology for the Bible*, Letter x. near the end.

[t] Idem, *Miscellan. Tracts*, l. c. — Dr. Law, Bishop of Carlisle, in his *Theory of Religion*, &c., which went through seven editions, asserts that the sentence of death passed upon Adam and Eve meant nothing less than a *total destruction of existence;* and that the idea of its implying a continuation of consciousness and real existence in some other place than earth, is not sanctioned by Scripture, but is the *philosophy of after-ages*. — p. 345. He adds, that Bishop Tillotson, though a patron of this notion, confesses it is not found in the Bible: and, after a critical and elaborate examination of the words used in Scripture to denote *soul* and *spirit*, and their various applications, he sums up the enquiry thus: — "But neither do *these words*, nor any other, so far as I can find, *ever* stand for a *purely immaterial principle* in man, or a substance, whatever some imagine they mean by that word, wholly separable from, and independent of, the body."

Bishop Sherlock employs strong expressions: — "Scholars may reason on the nature of the soul, and the condition of it when separated from the body: but the common hopes of nature receive no support from such enquiries. We die and moulder to dust; and in that state, what we are, or where we are, nature cannot say." *Discourse* ii. p. 85. and vol. iv. p. 79.

[u] Bishop Watson, *Apology*, l. c.

tion to be "*a mystery*:" it must, in truth, be a *miracle;* and therefore the enquiry, "how can these things be," altogether fruitless. The miracle of Christ's resurrection, to which the Scriptures refer us as the foundation of the hope of a future state, would not have been necessary to convince us of a necessary truth, discoverable by sense and reason. That the promises of the New Testament are the proper and *only* foundation of our hopes of immortality, was the opinion of the late Regius Professor of Divinity in the University of Cambridge, whose powerful intellect and sincere love of truth render his opinions weightier than the decrees of councils. "I have no hope of a future existence," says he, "except that which is grounded on the truth of Christianity."[x]

[x] *Anecdotes of the Life of* Richard Watson, D.D. F.R.S. late Lord Bishop of Llandaff. — Vol. i. p. 107. See also a very decisive passage, beginning — "As a Deist, I have little expectation; as a Christian I have no doubt, of a future state," in his *Apology for the Bible*, Letter x. near the end.

Bishop Jeremy Taylor, in his *Doctrine of Original Sin*, p. 24., assures us that the words — "Since by man came death, by man came also the resurrection from the dead," and, "as in Adam all die, even so in Christ shall all be made alive," directly affirm that a resurrection, or being *made alive again*, is granted, assured, and executed by and in Christ alone; and evidently suppose that the dead are not made alive till the resurrection, and that, had not a resurrection been provided, we should never, after death, have been made alive.

Locke argues, "that all the great ends of religion and morality are secured barely by the immortality of the soul, without a necessary supposition that it is immaterial." — *First Reply*, p. 34.

Mr. Dugald Stewart concedes that "the proper use of the doctrine of the immateriality of the soul is not to demonstrate that the soul is physically and necessarily immortal." l. c. p. 227.

Dr. Rush, of America, remarks upon this subject, "that the writers in favour of the immortality of the soul have done that truth great injury by connecting it necessarily with its immateriality. The immortality of the soul depends upon the will of the Deity, and not upon the supposed properties of spirit. Matter is in its own nature as immortal as spirit. It is resolvable by heat and moisture into a variety of forms; but it requires the same almighty hand to annihilate it, that it did to create it. I know of no arguments to prove the immortality of the soul but such as we derive from the Christian revelation." — *Medical Inquiries and Observations*, vol. ii. p. 15.

"I rather think," says Dr. Priestley, "that the whole of man is of some uniform composition, and that the property of perception, as well as the other powers that are termed mental, is the result (whether necessary or not) of such an organised structure as the brain. Consequently, that the whole man becomes extinct at death, and that we have no hope of surviving the grave, but what is derived from the scheme of revelation."—*First Introductory Essay to his Edition of Hartley*, p. xxiii. sq.

While those are wrong who think there can be any thing like an argument against a future life in another order of things, if declared by a revelation, it is strange that others should think it necessary to attempt rendering the pronunciations of scripture more probable, and that by an hypothesis which is at best but the remains of unenlightened times [y], and should require any as-

[y] The more uninformed the age, the greater the disposition to explain every thing. The savage personifies the winds and the heavenly bodies; the ancients fancied all matter endowed with a spirit — *spiritus intus alit.* Philo and Origen maintain that the stars are so many souls, incorruptible and immortal. In the older writings of the moderns, even in those of the father of experiment and observation — Lord Bacon, the properties of matter are referred to spirits: — "from them and their motions principally proceed rarefaction, colliquation, concoction, maturation, putrefaction, vivification, and most of the effects of nature;" "for tangible parts in bodies are stupid things, and the spirits do, in effect, all." (*Natural History*, cent. i. 98.) — In fact, some authors believe in three souls — the vegetable, sensible, and natural — for vegetables, brutes, and man; those which have the second having also the first, and those who have the third having all three. Paracelsus believed in four. These old writers, in providing a spirit for every thing, were more consistent than the moderns, who require it for only life and mind; because a subtle fluid or spirit is quite as necessary to explain the arrangement of saline particles into the regular form of a beautiful crystal. All these notions still exist among the vulgar; and the last remaining among the better informed, though it too is rapidly dying away, relates to mind. Those who upbraid others for refusing their assent to this hypothesis, may recollect that Anaxagoras and many more were accused of atheism and impiety, because they denied that the heavenly bodies were animated and intelligent. Even in the last reign but one, the Newtonian doctrines were thought irreligious by the Hutchinsonian sect, to which Bishop Horne, the amiable writer on the Psalms, and Mr. Jones, the learned and ingenious writer in defence of the Trinity, belonged: and the Jesuits, in their edition of Newton, 1742, carefully disclaim all belief in his demonstration of the earth's motion, as this is decreed false by the Pope.

Materialist is as good a word as any other for branding those from whom we differ; but materialism in its true acceptation signifies the doctrine of no first cause, or that all has been produced *ex fortuita atomorum collisione.* The whole tenor of scripture implies that *we* are *bodies* endowed with certain properties; and those passages from which our having a distinct immaterial substance is inferred, may be easily explained by the figurative style of the Bible, by the necessary adoption of the language of the times, and by the influence of the national opinions and prejudices of the writers on their modes of expression. Without due allowance, we might deem it impious to deny that "the round world cannot be moved;" that the sun "pursues its course" round the earth; (Galileo was imprisoned for doing so, and yet, said the sage to himself while in prison, "the earth does move" — *e pur si muove*:) that Naaman's leprosy (a condition of body) was a real substance, because we read that it left him and surance besides that of the gospel, which, they read, "has

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"clave unto Gehazi;" that Adam "surely" (more properly "utterly," "totally," or "entirely") died on the very day he tasted the forbidden fruit; that the winds possessed sense, because Christ said, "Peace, be still;" that the earth is square, because we twice read of its four corners (*Isa.* xi. *Rev.* vii.); and that Saul's melancholy, and the cases of insanity and epilepsy related in the New Testament, were possessions by demons, which are pronounced by St. Paul to be "nothing in the world." (See the Rev. Hugh Farmer's original and admirable works, especially his *Essays on the Demoniacs of the New Testament*, and *on Christ's Temptation*.) Without due allowance, what absurdities might not be inferred from Christ's use of the word heart? But the most enlightened divines allow us at present to follow Bacon's advice, and to read the Bible, not as a work of philosophical instruction, but of the revelation of religious matters beyond our knowledge, *v. c.* to learn from Genesis only how the world was created by God, and to study geology without reference to Moses. "The expressions of Moses are evidently accommodated to the first and familiar notions derived from the sensible appearances of the earth and heavens; and the absurdity of supposing that the literal interpretation of terms in Scripture ought to interfere with the advancement of philosophical enquiry, would have been as generally forgotten as renounced, if the oppressors of Galileo had not found a place in history." *A Treatise on the Records of the Creation*, &c., by J. B. Sumner, M. A., Prebendary of Durham, &c. now Bishop of Chester, 3d edit. 1825, vol. i. p. 327. We may, therefore, learn the miracle of the resurrection from the gospels, and enjoy our own opinions respecting matter and spirit, body and soul, which, as relating to our nature, are objects of physical enquiry, and therefore not of revelation, any more than astronomy or geology. The writer of the celebrated *Apology for the Bible* says, "when I went to the University, I was of opinion, as most schoolboys are, that the soul was a substance distinct from the body, and that when a man died, he, in classical phrase, breathed out his soul, *animam expiravit;* that it then went I knew not whither, as it had come into the body, from I knew not where nor when, and had dwelt in the body during life, but in what part of the body it had dwelt I knew not."—"This notion of the soul was, without doubt, the offspring of prejudice and ignorance."—"Believing as I do in the truth of the Christian religion, which teaches that men are accountable for their actions, I trouble not myself with dark disquisitions concerning necessity and liberty, matter and spirit; hoping as I do for eternal life through Jesus Christ, I am not disturbed at my inability clearly to convince myself that the soul is or is not a substance distinct from the body." —*Anecdotes of the Life of Bishop Watson*, p. 14. sqq.

"Well indeed is it for us," says a liberal writer in the *Quarterly Review*, on the subject of geology, "that the cause of revelation does not depend upon questions such as these; for it is remarkable that in every instance the controversy has ended in a gradual surrender of those very points which were at one time represented as involving the vital interests of religion. Truth, it is certain, cannot be opposed to truth. How inconsiderate a risk, then, do those advocates run, who declare that the whole cause is at issue in a single dispute, and that the sub-brought life and immortality to light.[z] They should reflect that the belief of an immaterial substance removes no imagined difficulty, as it is the peculiar doctrine of scripture, in distinction to that of most heathen philosophers and people[a], that the resurrection will be positively of *body*, — that in our *flesh* we shall see God[b], and that therefore our minds, according to the scripture doctrine, must appear as much a property of body hereafter as at present.[c]

Only this — the Christian — account of a future state is reason-

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stance of our faith hangs upon a thread — upon the literal interpretation of some word or phrase, against which fresh arguments are springing up from day to day!" 1823, April, p. 163.

The Theory of Religion, by the learned, able, and enlightened Bishop Law, already quoted, deserves to be read by every one, as proving that by the words *soul* and *spirit*, no immaterial, immortal principle in man is meant, but merely person, the superior and inferior mental faculties, living creature, &c.; by *death*, a total cessation of existence; by *the life hereafter*, a second *bodily* existence. It is to this admirable divine that Paley dedicates his *Principles of Moral and Political Philosophy*, and says — "Your Lordship's researches have never lost sight of one purpose, namely, to recover the simplicity of the Gospel from beneath that load of *unauthorised* additions, which the *ignorance* of some, and the *learning* of others; the *superstition* of weak, and the *craft* of designing men, have (unhappily for its interest) heaped upon it. And this purpose, I am convinced, was dictated by the purest motive; by a firm, and, I think, a just opinion, "that whatever renders religion more rational, renders it more credible: that he who, by a diligent and faithful examination of the original records, *dismisses* from the system one article which *contradicts* the apprehension, the experience, or the reasoning of mankind, does more towards recommending the belief, and, with the belief, the influence of Christianity, to the understandings and consciences of serious enquirers, and through them to universal reception and authority, than can be effected by a thousand contenders for creeds and ordinances of human establishment."

For an account of all the hypotheses that have been taught upon life and mind, see *An Enquiry into the Opinions, ancient and modern, concerning Life and Organisation*. By John Barclay, M.D., Edinb. 1822.

[z] 2 Timothy, i. 10.

[a] "Errant exsangues sine corpore et ossibus umbræ."—Ovid. *Metam.* iv.

[b] *Job.*

[c] It is the doctrine of the Church of England, that all men *shall rise with their bodies*. Enoch and Elijah are represented to have been translated *bodily*. Nay, our church has so little of this horror of matter, that it declares that Christ, "the very and eternal God" (Article ii.), ascended into heaven, and there sits, with "his body, with *flesh, bones,* and all things appertaining to the perfection of man's nature." Article iv.

able. The heathen doctrine was grounded on the supposed inherent immortality of a supposed substance distinct from the body. The Christian doctrine teaches the resurreetion of what we obviously are—*bodies,* and that through a *miracle* of the Almighty.[d]

[d] Respecting a difficulty which may present itself to the conceptions of some Christians, but which the *miraculousness* of a future existence, I think, should remove, I may quote Paley's sermon on the state after death. He concludes,

"That it is a question by which we need not be at all disturbed, whether the bodies with which we shall arise be new bodies, or the same bodies under a new form:

"For no alteration will hinder us from remaining the same, provided we are sensible, and conscious that we are so; any more than the changes which our visible person undergoes even in this life, and which from infancy to manhood are undoubtedly very great, hinder us from being the same, to ourselves and in ourselves, and to all intents and purposes whatsoever."—*Sermons on several Subjects,* by the late Rev. W. Paley, D.D. serm. 8. p. 96. These are a small system of divinity, and, having been bequeathed by him to his parishioners, probably contain his mature convictions.

II. SPECIAL PHYSIOLOGY.

CHAP. I.

HUNGER, THIRST, AND FOOD.

The solid and fluid substances, taken into the mouth to repair the losses of the system, are termed *food* and *drink;* or both are comprised under the word *food*.

The desire for the former is called *hunger* or *appetite*, and for the latter, *thirst*.

" Some ascribe *hunger* to an uneasiness arising in the stomach from its being empty and unoccupied; others, to the mutual friction of its rugæ; others, not only to the stimulus of its fluids, now secreted in abundance, — of the saliva and gastric juice, but to an acrimony which they acquire when food is not taken in proper time."

If hunger arise from merely a sense of vacuity in the stomach, why should it be increased by the application of cold to the surface, and instantly by the deglutition of cold liquids, &c.?

The explanation by friction of the rugæ is equally unsatisfactory; because the friction of these, if it does really occur, cannot be greater than the friction of the stomach against its contents immediately after a meal, when the organ is in great action, but at which time hunger does not exist.

Nor can the presence of the gastric juice explain the matter: because, as every one knows, no sensation arises in any other organ, which is not excrementory, from the peculiar stimulus of its natural fluid, and I presume that this is the stimulus intended, for the mechanical stimulus, from the bulk of the gastric juice, occurs equally from the presence of food, which does not excite hunger; because, if the hungry stomach is evacuated by vomiting, as in sea-sickness, the appetite, when the sickness has ceased, is even greater than before; and because hunger often ceases after a time, though the gastric juice still remains in the stomach, and is probably more abundant than ever.

The supposition of an acrimony generated in the gastric juice, &c. being a cause of hunger, is absurd. The fluid would be unfit for its purposes, and would be more likely to destroy than produce appetite.

Hunger has been attributed by some to a sympathy of the stomach with a general feeling of want in the system. But hunger is removed *immediately* that a due quantity of food is swallowed,—long before the general system can have derived benefit from the meal: fowls are satisfied when their crops are filled, although their food is not even ground, *preparatorily* to digestion, till it has passed from the crop into the gizzard; and ruminating animals leave off eating before they begin to chew the substances with which they have distended their stomachs. Again, persons unable to obtain food in sufficient quantity lessen their hunger by swallowing any innutritious and indigestible matter. The circumstance giving rise to this opinion is the continuance of hunger although food be taken in abundance, in cases of scirrhous pylorus and enlarged mesenteric glands. Here, it is urged, the hunger continues, because the body receives no nourishment. But, in scirrhus of the pylorus, vomiting generally soon follows the reception of food into the stomach; and therefore this organ is reduced to the condition in which it was previously, and the return of hunger is easily explicable: but I do not know that a continued hunger commonly occurs in cases of scirrhous pylorus. In diseases of the mesenteric glands there is, in fact, no obstruction to the course of the chyle. They are found permeable, according to Dr. Boekker, a German anatomist, and the continued hunger appears rather a part of the diseased state of the chylopoietic viscera. Besides, many cases of imperfect nutrition, from various causes, occur, without any increase of appetite:—and where there is an increase of appetite, the process of digestion seems to proceed with unusual rapidity, so that the stomach becomes empty sooner than in health.—In continued abstinence, although the system is daily more in want, hunger usually ceases after a few days, whether from the stomach falling into a state of relaxation, becoming distended with wind, or from other circumstances.

If hunger arose from fatigue of the stomach, it should be greatest immediately after the laborious act of digestion, and gradually decrease: but it on the contrary increases.

Were irritation the cause, hunger should be greatest when the stomach is filled with food.

On the whole, hunger may perhaps be regarded as a sensation connected with the contracted state of the stomach.

It occurs when the stomach, being empty, must be contracted, and is increased *instantaneously* by a draught of cold liquid, which cannot but contract the stomach, and corrugate its inner coat: acids, bitters, and astringents have the same effect, and from their nature they may be supposed to act in the same way. Cold air applied to the surface increases it, and, in all probability, by a similar operation; for the impression of cold upon the skin excites an attempt at evacuation in the urinary bladder, and, when all other means fail to induce the intestines to expel their contents or the uterus to contract after delivery, the affusion of cold water so frequently succeeds, that the omission of the practice in obstinate cases is highly censurable. It is diminished by heat and every thing which relaxes. Again, it ceases immediately that the stomach is filled and thus the organ dilated and all corrugation removed; and, the more the contents of the stomach are of a nature to be absorbed or passed into the duodenum, the sooner it recurs. Distension of the stomach is universally acknowledged to be incompatible with hunger; whence the proverb, — " a *full* belly loathes the honey-comb."

The Otomacs during the periodical inundation of the rivers of South America, when the depth of the waters almost entirely prevents fishing, appease their hunger for two or three months by distending their stomach with prodigious quantities, a pound a day and upwards, of a fine unctuous, strong-smelling, yellowish-grey clay, slightly baked, and destitute of all organic substance, oily or farinaceous.[a] The savages of New Caledonia, in the Pacific Ocean, in times of scarcity, do the same by eating a friable lapis ollaris, consisting of equal parts of magnesia and silex, with a little oxide of copper. The wolves, rein-deer, and kids of Siberia, when pressed by hunger in winter, also devour clay or friable steatites. The Kamtschatkans sometimes appease their hunger by distending their stomach with sawdust, for want of something better.

Being, in this view, a sensation connected with a local state of the stomach, it will be affected not only by whatever affects this state, but by whatever affects also the sensibility to this state, and

[a] Humboldt, *Tableaux de la Nature*, t. i. They become so fond of it, that they take a little, even when well provided with sustenance, and are compelled to tie their children's hands to prevent them from *geophagising*.

therefore be subject to the common laws of sensation. Hence uncivilised tribes enable themselves to traverse large tracts without food by swallowing pills containing tobacco or opium. The pain of all excessive muscular contraction is lessened by pressure; whence the uneasiness of hunger is lessened by a belt fixed tightly over the stomach; and some Northern Asiatic tribes really place a band there, and lace it behind with cords drawn more tightly, according to the degree of the uneasiness. Thus, too, the state of the stomach remaining the same, hunger may diminish from the occurrence of other feelings which attract our attention more forcibly, by passions of the mind, &c.: as is exactly the case with all other sensations, even with those that are morbid. Under strong attention of the mind to pursuits of either intellect or passion, to delightful or painful sensation, all other feelings cease to be felt, although really violent; and frequently, from being unattended to, do not recur. Passions, however, and the narcotic pills of savages, may affect hunger, not only by increasing or diminishing the sensibility to the state of the stomach, but by increasing or diminishing this state — the cause of the sensation.

As hunger appears to depend upon the local condition of the stomach, so does *thirst* more evidently upon that of the mouth and fauces. Every consideration renders it probable that thirst is the sensation of the deficiency of moisture in the parts in which it is seated. Whatever produces this, either by causing the fluids of the mouth and fauces to be secreted in small quantity or of great viscidity, or by carrying off the fluid when secreted, produces thirst; and vice versâ. *To be dry* means to be thirsty, because the state is removed by directly wetting the parts, or by supplying the system with fluid. that they may be moistened by their own secretions. Being a sensation, the same may be repeated in regard to it as was observed respecting hunger. Rage or terror dry up the mouth and throat, and cause violent thirst. Thirst is only momentarily assuaged by wetting the mouth and throat, because they presently grow dry again. Fluids must be swallowed to be effectual, that they may be absorbed and the part thus preserved moist by constant secretion.

" The necessity of obeying those stimuli is greater or less, according to age, constitution, and especially according to habit, and nothing can therefore be affirmed positively respecting its urgency; but a healthy adult, in whom all the calls of nature are felt in their usual force[b], cannot abstain from food a whole day without great prostration of strength, nor scarcely beyond eight days without danger to life."

Hippocrates says that most of those who abstain from food for seven days, die within that period; and, if they do not, and are even prevailed upon to eat and drink, that still they perish.[c] Sir William Hamilton, however, saw a girl, sixteen years of age, apparently not in bad health, who was extricated from the ruins of a house at Oppido, in which she had remained eleven days without food: an infant in her arms, but a few months old, had died on the fourth day, as the young are never so able to endure abstinence.[d] A moderate supply of water lengthens life astonishingly. Dr. Willan was called to a young gentleman who had voluntarily abstained from every thing but a little water, just flavoured with orange *juice*, for sixty days: death ensued a fortnight afterwards.[e] Redi cruelly found that of a number of starved fowls deprived of water, none lived beyond the ninth day, whereas one indulged with water lived upwards of twenty.[f] If the water is not swallowed, but imbibed by the surface or lungs, it may also prolong life. Fodéré mentions some workmen who were extricated alive at the end of fourteen days from a cold damp cavern in which they had been buried under a ruin.[g]

In abstinence equally great imbecility of mind takes place as of body: extreme emaciation and œdema of the legs present a frightful spectacle; urine may still be secreted, but the alvine discharge is greatly diminished, or suppressed altogether; the pain

[b] "Consult, among innumerable writers on long fasting, James Barthol. Beccarius, *Commentar. Instituti Bononiens.* t. ii. p. 1.; and Flor. J. Volteleu, *Memorab. Apositiæ Septennis Hist.* Lug. Bat. 1777, 8vo."

[c] *De Carnibus.*

[d] *Phil. Trans.* vol. lxxiii. p. 191. sq.

[e] *Medical Communications,* vol. ii.

[f] *Osservaz. intorno agli anim. viventi.*

[g] Fodéré, *Médecine Légale,* t. ii. p. 285. A hog, weighing about 160 lbs., was buried in its sty, under thirty feet of the chalk of Dover Cliff, for 160 days. When dug out it weighed but 40lbs., and was extremely emaciated, clean, and white. There was neither food nor water in the sty when the chalk fell. It had nibbled the wood of the sty, and eaten some loose chalk, which from the appearance of the excrement had passed more than once through the body. (*Linnæan Transact.* vol. xi. See *London Med. Journ.* vol. xxxv. 1816.) Pigs will not only eat coals, but keep in good condition upon them alone. Coals, however, are a vegetable substance. — Cuninghani's *Two Years in New South Wales,* vol. i. p. 301.

of hunger ceases in a few days[h], probably from relaxation of the stomach through debility. But when hunger has ceased, though no food has been taken, weakness and sinking at the pit of the stomach are still felt.

Life may be supported for a certain time by nutriment introduced into the intestines. I lately attended a lady who, through obstruction of the œsophagus, attended by suppuration, *did not swallow a particle of solid or fluid for six weeks*, at the end of which she died. Three injections of milk, eggs, and wine, were employed daily. She passed a feculent soft evacuation in every twenty-four hours, and never felt the sensation of hunger.

A poor diet, even of vegetable matter, sometimes gives rise to symptoms of scurvy[i]; and famine is soon attended by epidemic fever.

The torment of thirst increases until drink is procured or moisture applied to the surface or inhaled: inflammation of the mouth and throat, and intense fever, at length ensue.[k]

If abstinence is not forced upon the system, but is absolutely a part of disease, it may, like suspension of respiration in morbid states of insensibility[l], and like immense doses of powerful medi-

[h] Among many other accounts of starvation, some of these facts may be seen in Captain Franklin's *Narrative of a Journey to the Polar Sea*, p. 465. sq. 427. London, 1823; where the dreadful force of hunger is too truly illustrated. Our countrymen devoured their old shoes, and any scraps of leather they possessed. (pp. 418. 429. 438. 479.). The putrid spinal marrow left in bones, picked clean by wolves and birds of prey, was esteemed a prize, though its acrimony excoriated the lips; the bones were also eaten up after being burnt (p. 426.); great part of a putrid deer was devoured on the spot (p. 421.); and to destroy, skin, and cut up a cow, was the work of a few minutes, after which the contents of the stomach and the raw intestines were at once devoured and thought excellent. (p. 407.) In the siege of Jerusalem and other ancient cities, we read of women driven by hunger to devour their offspring; and Captain Franklin was assured, near the Saskatchawan, that men and women were then living, who had destroyed and fed upon the bodies of their own families, to prevent starvation in very severe seasons. (p. 51.)

[i] See Sir George Baker's account of two women, in the *Transact. of the College of Physicians*, vol. ii.

[k] A horrid description of raging thirst will be found in the account of the black-hole of Calcutta. See *Annual Register*, 1758.

[l] An example of the impunity with which a long exclusion of air may be borne, when the system is in a morbid nervous state, may appear to advantage by the side of similar illustrations of the deprivation of food. "The story of Ann Green," says the Rev. Mr. Derham, "executed at Oxford, Dec. 14. 1650, is still well

cines in various diseased states, be borne with wonderful indifference; and this occurs chiefly among females. But the most extraordinary case that I recollect, stated upon unquestionable authority, is that of a young Scotchwoman, who laboured under an anomalous nervous affection, and, excepting that on two occasions she swallowed some water, received no nourishment whatever for eight years. She passed urine enough twice a week to wet a shilling, and for three years had no intestinal evacuation.[m]

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remembered among the seniors there: she was hang'd by the Neck near half an Hour, some of her Friends thumping her on the Breast, others hanging with all their Weight upon her Legs, sometimes lifting her up and then pulling her down again with a sudden Jirk, thereby the sooner to dispatch her out of her Pain, as the printed Account of her informs us. After she was in her Coffin, being observ'd to breathe, a lusty Fellow stampt with all his Force on her Breast and Stomach, to put her out of Pain. But, by the Assistance of Dr. Peity, Dr. Willis, Dr. Bathurst, and Dr. Clark, she was again brought to Life. I myself saw her many Years after, between which Time and the Date of her Execution she had, as I am inform'd, borne several Children." (*Physico-Theology*, p. 156.) Her nervous insensibility appears from another writer, who states, that "she neither remembered how the fetters were knocked off, how she went out of prison, when she was turned off the ladder, whether any psalm was sung or not, nor was she sensible of any pain that she could remember. What is most remarkable is, that she came to herself as if she had awakened out of a sleep, not recovering the use of her speech by slow degrees, but in a manner altogether, beginning to speak just where she left off on the gallows." (Plott's *History of Oxford.*)

[m] *Phil. Trans.* vol. lxvii. In a remarkable instance of imperfect abstinence during fifty years, the woman voided a little feculent matter like a piece of roll-tobacco, or a globule of sheep's dung, but once a year, and that always in March, for sixteen years. (*Edinb. Med. and Phys. Essays*, vol. vi.) It would be interesting to examine the changes induced in the air by the lungs and skin of such patients.

Pouteau mentions the case of one of his patients, a young lady thirteen years of age, who was affected with convulsions and insensibility at a certain period, generally every day, sometimes not quite so often, and great irritability of stomach, lived eighteen months, and grew more than two inches and a half, on syrup of capillaire and cold water. Here, the abstinence was not part of the disease, but the extraordinary state of the system enabled it to bear the abstinence. *Œuvres Posthumes*, t. i. p. 27.

Still, many cases of abstinence have been impostures and exaggerations; and I cannot illustrate this better than by quoting the case of Eue Fleigen, the Dutch prototype of our own Anne Moore of Tutbury. She contrived to deceive the world for fourteen years (from 1597 to 1611), pretending that she took no nourishment all that time. She had no nervous derangement to render food

For every example of extraordinary abstinence among females we have a counterpart in voraciousness among males. When the appetite is so great, it is seldom nice; and not only all animals in all states are devoured, but glass, flints, metals, sand, wood, &c. A Frenchman, named Tarare, and described by Drs. Percy and Laurent, in some measure from their own observation [n], will form a good contrast to the Scotch girl. When a lad, he once swallowed a large basket of apples, after some person had agreed to pay for them; and at another time a quantity of flints, corks, and similar substances. The colic frequently compelled him to apply at the Hôtel Dieu: he was no sooner relieved, however, than he began his tricks again, and once was but just prevented from swallowing the surgeon's watch, with its chain and seals. In 1789 he joined the mob, and obtained sufficient food without devouring for money. He was then about seventeen, weighing a hundred pounds, and would eat five-and-twenty pounds of beef a day. When the war broke out he entered into the army, and devoured his comrades' rations, as long as better supplies from other sources rendered them of little value. But when at length his comrades stood in need of them themselves, he was nearly famished, fell ill, and was admitted into the *hôpital ambulant* at

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unnecessary; yet the minister and magistrates of Meurs made trial of her for thirteen successive days without detecting her imposture. Over her picture in the Dutch original are these lines: —

> Mueræ hæc quam cernis decies ter sexq; peregit
> Annos, bis septem prorsus non vescitur annis
> Nec potat, sic sola sedet, sic pallida vitam
> Ducit, et exigui se oblectat floribus horti.

Thus rendered in the English translation —

> This maide, of *Meurs* 36 yeares spent
> 14 of which she tooke no nourishment
> Thus pale, and wan she sits sad and alone
> A garden 's all shee loves to looke upon.

An Apologie or Declaration of the Power and Providence of God. By George Hakewill. 1630. fol.

Respecting Anne Moore, see Dr. Henderson's *Examination*, &c.

[n] *Dictionnaire des Sciences Médicales*, art. Homophage; where the dissection of another polyphagus is given, whose stomach was found to have been made neither more nor less than a collection of marine stores. See also Percy's *Mémoire sur le Polyphage*, in the *Journal de Médecine*, Brumaire, An xii.

Sultzer. He there ate not only a quadruple allowance, the broken food of the other patients, and the waste of the kitchen, but would swallow the poultices and any thing else that came in his way. He devoured so many dogs and cats alive that they fled at the sight of him. Large snakes he despatched with the greatest facility; and once gobbled up in a few moments all the dinner that was provided for fifteen German labourers, viz. four bowls of curd, and two enormous dishes of dough boiled in water with salt and fat. At another time, he disposed of thirty pounds of raw liver and lights in the presence of some general officers, who, finding that he could swallow a large wooden lancet case, took the partitions out, enclosed a letter in it, and made him swallow it, and proceed to the enemy's quarters for the purpose of discharging it by stool, and delivering the letter to a French colonel who had fallen into the hands of the Prussians. This he contrived to do, enclosed the answer in it, swallowed it again, made his escape, discharged the case again from his bowels, washed it, and presented it to Beauharnois and the other officers. Having, however, been well drubbed by the enemy, he refused any further secret service, and was readmitted into the hospital to be cured of his hunger. Being no longer a novelty, he excited less interest, and felt it necessary to have recourse to sheepfolds, poultry-yards, private kitchens, slaughter-houses, and by-places, where he had to contend with dogs and wolves for their filthy food. He was detected drinking blood that had been taken from his fellow-patients, and eating bodies in the dead-house. The disappearance of a young child excited strong suspicions against him, and he was at length chased away and unheard of for four years, at the end of which time he applied at the Hospice de Versailles, wasted, no longer voracious, and labouring under a purulent diarrhœa; and he soon died, aged twenty-six. The body immediately became a mass of putridity. During his life he was always offensive, hot, and in a sweat, especially at intervals. His breath rolled off like steam, and his dejections were constantly very copious, and intolerably fœtid. He was of the middle height, thin, and weak.

All the abdominal viscera were found full of suppurations.

His stomach was of immense size, and this has usually been the case in persons habitually gluttonous. A polyphagous idiot opened by the same writers displayed an enormous stomach, more resembling that of a horse than of a human being: the intestines also formed several large pouches in succession, which appeared like additional stomachs. Cabrol dissected a glutton of Toulouse, and found the œsophagus terminating in an excessively large cavity, and the intestines running, without a single convolution, but with merely a gentle sigmoid flexure, to the anus. A large pylorus, or a very depending position of it, have been found in other cases. We thus learn the common causes of constitutional voraciousness, and obtain an additional reason for referring hunger to the want of distention of the stomach : — a great quantity of food is required to *fill* these stomachs. If hunger were independent of the distention of this organ, and connected solely with the want of the system, an ordinary meal would suffice where the stomach is very large, as the extraordinary quantity of food cannot be demanded for nourishment, — when food enough for support is taken, hunger should cease. But hunger continues till the stomach is filled, and the prodigious collection in the case of Tarare was disposed of by abundant stools, sweating, and copious pulmonary exhalation.

The large capacity of the stomach is generally ascribable to original conformation, but some account for it occasionally by repeated over-distention and the deglutition of indigestible substances, — an opinion rather improbable, when we reflect that corporation gluttons, who give a very fair trial to the distensibility of their idol, never acquire such appetites and capaciousness of stomach as qualify them for a show. The power of deglutition may be very much increased by practice. We have all seen the Indian jugglers ; and I frequently conversed with a poor man who had swallowed nineteen large clasp-knives at different times, having found in a drunken fit that he could get one down his throat for a wager[o] : yet in him the appetite and capacity of stomach were not augmented. Knife and stone eaters are seen in all countries.

Some great eaters are prodigies of strength; as Milo, who killed

[o] Several pieces of the knives are preserved in the Museum of Guy's Hospital, and an account of the case may be found in the *Med. Chir. Trans.* vol. xii.

There is a collection of cases of extraordinary swallowing from Galen, Vesalius, Paré, &c., in Shenkius, *Observationes Medicæ*, lib. iii.

A polyphagus at the *Jardin des Plantes*, who once ate a lion which had died there of some disease, and at last died himself of eating 8lbs. of new bread, most originally conceived, being all for the belly, that animals might be classed according to their excrement, and actually made a collection of such stores, upon which he would descant most eloquently. *Dict. des Sc. Méd.*, Cas. Rares, p. 199.

an ox with a blow of his fist, and devoured it; and the fellow mentioned in a thesis published at Wittemberg in 1757, who once, in the presence of the senate, ate up a sheep, a sucking-pig, and sixty pounds of plums, stones and all, and could carry four men a whole league upon his shoulders.

Voracity is of course sometimes, like depraved appetite, as in chlorosis and pregnancy, but temporary, and referable to merely disordered function. Dr. Satterly details the case of a lad in whom, while labouring under typhus with marked inflammation in the head, the exacerbations of fever were accompanied by such hunger, that he ate every day four regular meals, each sufficient for the stoutest labourer's dinner, and many pounds of dry bread, biscuit, and fruit between them. He had no sooner finished a meal than he denied having tasted any thing,

——— "cibus omnis in illo,
Causa cibi est, semperque locus fit inanis edendo,"

and would suck and bite the bed-clothes or his fingers[p] if refused more, cared nothing about the quality of what he ate, would pass six or seven large solid motions a day by means of physic, and ultimately recovered.[q] The stomach here executed its office with excessive rapidity, and was too soon empty again.

To show how some animals differ from us in the demand for food, I may mention that the ant-lion will exist without the smallest supply of food, apparently uninjured, for six months; though, when he can get it, he will daily devour an insect of his own size. A spider has lived without food under a sealed glass for ten months, and at the end of that time appeared as vigorous as ever. Reptiles have often lived upwards of a century enclosed in trees or stones.

On the other hand, herbivorous larvæ, as caterpillars, (for insects are carnivorous, herbivorous, and omnivorous, like their superiors,) will eat twice their weight of food daily.[r]

[p] Ovid's account of Erisichthon is verified in many histories of voracity:—

"Ipse suos artus lacero divellere morsu
Cœpit; et infelix minuendo corpus alebat." *Metam.* lib. viii.

[q] *Transactions of the Royal College of Physicians, London*, vol. v. See also *Phil. Trans.* Papers read 1745; and Abridgment, vol. iii. p. 111.

[r] Kirby and Spence, *Entomology*, p. 398. sq.

"Although thirst is a violent desire, drink appears not very necessary to life and health; for many warm-blooded animals — mice, quails, parrots, &c. — do not drink at all; and some individuals of the human species have lived in perfect health and strength without tasting liquids."[s]

Sauvages mentions a member of the Academy of Toulouse who never thirsted, and passed whole months of the hottest summer without drinking; and a woman who passed 40 days without liquids or thirst.[t]

"It has been disputed whether our *food*, by which we satisfy these stimuli, is derived more advantageously, and the more consistently with nature, from the animal or from the vegetable kingdom.[u]

"Some contend that man is herbivorous, from the shape of his teeth[x], the length of his intestines[y], the difference between the structure of the small and large intestines, and from the cells of the colon, &c. Rousseau ingeniously urges the circumstance that woman is naturally uniparous and provided with two breasts.[z] To these arguments it may be added, that some men have ruminated,—a power peculiar to herbivorous animals[a], and that tame

[s] "See G. Baker, *Med. Transact. published by the Coll. of Physicians in London*, vol. ii. p. 265. sq."

[t] "*Nosol. Méthod.* t. i. p. 770.

See also *Eph. Nat. Cur.* c. v. and vi. p. 30."

[u] "J. W. Neergaard, *Vergleichende Anatomie und Physiologie der Verdauungswerkzeuge der Saügethiere und Vogel.* Berlin, 1806, p. 244."

[x] "Gassendi, *Letter* to J. Bapt. v. Helmont. Opera. Florence, 1727, fol. t. vi. p. 17. Al. Monro, senr. *Essay on Comparative Anatomy*, p. 17."

[y] "J. Wallis, *Phil. Trans.* No. 269."

[z] "*Sur l'Origine de l'Inégalité parmi les Hommes*, p. 196. sq."

[a] A striking instance of this occurred at Bristol. A *man* twenty years of age had, as long as he could remember, chewed his food a second time, after swallowing it. The process began in a quarter of an hour if he had taken liquid at his meal — later if he had not: and, after a full meal, lasted about an hour and a half. What had passed down first, always came up first. Before the second chewing, his food appeared to lie heavy in the lowest part of his throat: after it, "the food passed clean away." If he ate a variety, "that which passed down first came up first." He found the taste of the food on its return to be chewed rather pleasanter than at first. "If this faculty left him it signified sickness, and he was never well till it returned." His father had sometimes ruminated slightly. (*Phil. Trans.* Abridgment, vol. iii. p. 110. sq.)

vegetable feeders are easily accustomed to animal food; whereas carnivorous animals, excepting the dog, can very seldom be brought to feed on vegetables.

" The arguments of those who, with Helvetius [b], regard man as carnivorous, are derived from the conformation of his stomach, the shortness of his cæcum, &c.

"More careful observation, however, proves that man is not destined for either kind of food alone, but for both. His teeth, particularly the molares [c], and the peculiar structure of his intestines just alluded to, hold a middle rank between the same parts in the feræ and in herbivorous animals." In carnivorous animals, the incisors are very large; and the molares generally of an irregular wedge form, those of the lower jaw closing in those of the upper like scissors, and being adapted for lacerating. In the herbivorous, the surface of the molares is horizontal or oblique, adapted for grinding. As the food of herbivorous animals requires more preparation before it becomes the substance of the animal, their stomach is adapted to retain it for a length of time. The œsophagus opens nearer the right extremity of the stomach, and the pylorus nearer the left, so that a blind pouch is left on either side. In the carnivorous, the reverse is the case, and the stomach cylindrical, to favour the quick passage of the food. For the same reason, the intestines in the latter, even among insects, are generally shorter, and have fewer valvulæ conniventes, and in some instances no cæcum.

Blumenbach has seen four examples of this kind: in two the process was compulsory, in two it was optional. These subjects also were *males*, and had a real gratification in ruminating. *Comparative Anatomy*, translated by Messrs. Lawrence and Coulson, 2d edit. p. 88. A case of human rumination, in a *man*, has lately been seen at the London Hospital. *London Medical Gazette*, June 23. 1832.

[b] " *De l'Homme*, t. ii. p. 17."

[c] " The opinion of Broussonet is singular. He thinks the human molares closely resemble the teeth of herbivorous animals, and at the same time regards the incisores and canini as allied to those of the carnivorous tribes: and, after comparing the *number* of the molares with that of the other teeth, concludes that the quantity of vegetable food intended for man is to the quantity of animal food as 20 to 12.

" But on this calculation it follows, that infants, who have four molares only in each jaw, are destined to consume a larger portion of animal food than adults, since the proportion of the molares to the other teeth is in them as 8 to 12."

"The mode in which the condyles of the lower jaw are articulated with the temporal bones, demonstrates his destination for both kinds of food in the most striking manner." In animals which subsist on animal food, the condyles of the lower jaw are locked in an elongated glenoid cavity, and all rotatory motion thus prevented, as motion upwards and downwards is sufficient for the laceration of the food. In vegetable feeders the joint is shallow, so that a horizontal motion is allowed for grinding the food. Its nature in man is explained at the beginning of the next chapter.

"As the human race exists in more parts of the globe than any other kind of animal, we should have been but ill provided for if we had been destined to subsist on either description of food alone; whereas man now inhabits some countries which afford either vegetable or animal food only.

"Man is by far the most omnivorous of all animals, capable not only of feasting on luxurious combinations derived from each kingdom, but of subsisting with health and vigour on nearly one kind of the most simple food.

"Thus, to mention a very few instances, many at present live on vegetables only, as the tubera of solanum (potatoes), chestnuts, dates, &c. The first families of mankind most probably subsisted for a long period merely on fruits, roots, corn, and pulse.[d]

"The nomadic Moors have scarcely any other food than gum senega[e]:

[d] "Consult Heyne, *Opuscula Academ.* vol. i. p. 366. sq."

[e] "Adamson, *Mém. de l'Acad. des Sc. de Paris*, 1778, p. 16."

In 1750, a caravan of Abyssinians had consumed all their provisions, and would have starved but that they discovered among their merchandise a stock of gum-arabic, on which alone above a thousand persons subsisted for two months. (Hasselquist, *Voyages and Travels in the Levant*, p. 298.) Yet Dr. Magendie says he finds that dogs perish if fed only with gum or sugar, olive oil, butter, and similar articles, regarded as nutritious, which contain no azote. (*Annales de Chimie et de Physique*, vol. iii. p. 66. 1816.) But although such substances be alone unable to nourish, yet when united with others they may afford some support; for persons accustomed to a mixed diet generally grow thinner if they confine themselves to vegetable food, which is indubitably good nourishment: and even if we grant that such substances are not nutritious to dogs, they may be proper food for other species: and to render it probable even that these are not nutritious to dogs, the animals should have been gradually brought to feed on them only; for animals may be brought to live on food the most opposite to what their nature inclines them, if the change is made insensibly: — Spallanzani

"The inhabitants of Kamtschatka and many other shores scarcely any other than fish.

"The shepherds in the province of Caraccas in South America, on the banks of the Orinoko [f], and even the Morelachs [g] in Europe, live almost entirely on flesh.

"Some barbarous nations devour raw animals. This cannot be denied to have formerly been the case with the Samojedes [h], the Esquimaux [i], and some tribes of South America.[k]

"Other nations are no less remarkable in their drink.

"The inhabitants of many intertropical islands, especially in the Pacific Ocean, can procure no sweet water, and instead of it drink the juice of cocoa-nuts.

"Others take only sea-water; and innumerable similar facts clearly prove man to be omnivorous."

It appears that matter, as in the case of water, which has never belonged to an animated system, is calculated to afford nourish-

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made a pigeon live on flesh, and an eagle on bread. (*Expériences sur la Digestion*, c. lxxiv. c. lxxv.) If fresh-water mollusca are put at once into sea water, or sea-water mollusca into fresh water, they perish; but if the change is gradually made, they live very well. (*Annales de Chimie et de Physique*, vol. ii. p. 32. 1816.) A spider has fed upon sulphate of zinc. (Thomson's *Annals of Philosophy*, vol. xii. p. 454.) We have seen that the Otomacs eat little else some months of the year than large quantities of earth, and that some brutes devour earth. I may here add that not only the Otomacs are so fond of it, as, when well supplied with food, to take a little, but that many nations of the torrid zone have a propensity to geophagism. The negroes of Guinea, the Javanese, the New Caledonians, and many South American tribes, eat clay as a luxury; and the Guajeroes, on the west of Rio da la Hache, carry a little box of lime as sailors do a tobacco-box. German workmen at the mountain of Kifflhönser spread clay instead of butter on their bread, and call it *stein butter*, and find it very satisfying and easy of digestion. The Otomacs do not suffer by the practice, but in some tribes the people grow sick and thin by indulging too freely in this luxury. Africans who geophagised with impunity at home on a yellow clay, severely suffer from it in the West Indies. (See also Dr. John Hunter, *Diseases of the Army in Jamaica*, p. 248. sqq.) The red clay eaten in Java destroys the appetite and wastes the body.

[f] "Fil. Salv. Gily, *Saggio di Storia Americana*, vol. iv. p. 120."

[g] "Gius. Ant. Pujati, *Reflessioni sul Vita Pitagorico*. Feltri, 1751, 4to."

[h] "De Klingstaedt, *Mém. sur les Samojedes et les Lappons*. 1762, 8vo."

[i] "Curtis, *Phil. Trans.* vol. lxiv. p. ii. p. 381. 383."

[k] "J. Winter, in Hakluyt's *Principal Navigations of the English Nation*, vol. iii. p. 751."

ment to animals in some degree, but subordinately to matter which has belonged to vegetables or animals, and that it alone will in some instances support life for a time. Vegetables live chiefly on such, and will indisputably live for a time with facility on them alone, and some even if merely suspended in the air[l] (carbonic acid is, indeed, the great nourishment of all vegetables), but eventually will not thrive and perfect their seed, unless animal or vegetable remains exist in the soil; whence the necessity of this kind of manure, which must have likewise been so changed by putrefaction that its carbon has formed a compound resembling the extractive principle and thus capable of solution in water.[m] It has been contended that some animals, as fish, and that some vegetables, readily subsist, growing equally with others, and perfecting their seed or ova, on simple water; but the experiments in support of this assertion are not at all decisive.[n] None of these statements are affected by the derivation of *gaseous* substances from the surrounding air or water, by animals or vegetables.

The articles of diet generally employed by every nation and class of society are much determined by the facility with which they are procured. Generally, too, animal food is preferred in cold climates, and vegetable in warm: a mixture, however, of the two is usually preferred to either exclusively, and appears better suited to our necessities. Animal food is chiefly muscle and fat, milk and eggs; vegetable food, chiefly seeds and roots, fruits and leaves, with more or less of the stalks. These articles, which are rendered more or less masticable or digestible by heat, are previously subjected to high temperatures in various ways; and as many saline and aromatic substances are taken, not so much for their nutritive qualities and their undoubted assistance when the stomach is weak or chiefly vegetables are eaten, as for their sapid qualities, and since the admixture of these, and the combination

[l] Two fig plants (*Ficus australis* and *Ficus elastica*) have continued to send out shoots and leaves, the former for eight, the latter for fourteen, years, suspended in the hot houses of the Botanical Garden of Edinburgh. — *Elements of Chemistry*, by Dr. Turner, Professor of Chemistry in the University of London, 1833. p. 862. sq.

[m] Mould consists principally of carbon, combined with a little oxygen and hydrogen, and, if it be animal, with also a little azote, together with the usual saline ingredients of organised substances.

[n] Full information on this subject will be found in Dr. Thomson's *System of Chemistry*, book iv. ch. 3. sect. 2.

of various nutritive substances together, often highly increase the exquisiteness of taste and flavour, the culinary art is cultivated not only for health, but also for luxury.

The chief proximate principles of animal food are fibrin, albumen, gelatine, oil, and sugar; of vegetable, gluten, fecula, mucilage, oil, and sugar. My not less excellent than distinguished friend, Dr. Prout, in the paper which was honoured with the Copley medal of the Royal Society [o], reduces all the articles of nourishment among the higher animals to three classes: the saccharine, oily, and albuminous. The first comprehends sugars, starches, gums, acetic acid, and some other analogous principles; the second, oils and fats, alcohol, &c.; the third, fibrin, gelatine, albumen, and caseum or the curd of milk, with vegetable gluten, so abundant in wheat. He has favoured me with the following remarks, which are chiefly an abstract from a work on digestion, commenced by him in 1823, but not yet published.

" Observing that milk, the only article actually furnished and intended by nature as food, was essentially composed of three ingredients, viz. saccharine, oily, and curdy or albuminous matter, I was by degrees led to the conclusion that all the alimentary matters employed by man and the more perfect animals might, in fact, be reduced to the same three general heads; hence I determined to submit them to a rigorous examination in the first place, and ascertain, if possible, their general relations and analogies. An account of the first of these classes, viz. the saccharine matters, has been published in the *Philosophical Transactions*, and the others are in progress. The characteristic property of saccharine bodies is, that they are composed simply of carbon united to oxygen and hydrogen in the proportions in which they form water; the proportions of carbon varying in different instances from about 30 to 50 per cent. The other two families consist of compound bases (of which carbon constitutes the chief element) likewise mixed with and modified by water, and the proportion of carbon in oily bodies, which stand at the extreme of the scale in this respect, varies from about 60 to 80 per cent.; hence, considering carbon as indicating the degree of nutrition, which, in some respects, may be fairly done, the oils may be regarded in general as the most nutritious class of bodies; and the general conclusion from the whole is, that substances *naturally* containing

[o] *Phil. Trans.* 1827.

less than 30 or more than 80 per cent. of carbon are not well, if at all, adapted for aliment.

"It remains to be proved whether animals can live on one of these families exclusively; but at present experiments are decidedly against this assumption, and the most probable view is, that a mixture of two at least, if not of all three, of the classes of nutriment, is necessary. Thus, as has been stated, *milk* is a compound of this description, and almost all the gramineous and herbaceous matters employed as food by animals contain at least two of the three — the saccharine and glutinous or albuminous. The same is true of animal aliments, which consist, at least, of the albuminous and oleaginous: in short, it is, perhaps, impossible to name a substance employed by the more perfect animals as food, which does not essentially constitute a natural compound of, at least, *two*, if not of all *three*, of the above three great classes of alimentary matters.

"But it is in the artificial food of man that we see this great principle of mixture most strongly exemplified. He, dissatisfied with the productions spontaneously furnished by nature, culls from every source, and, by the power of his reason, or, rather, his instinct, forms, in every possible manner, and under every disguise, the same great alimentary compound. This, after all his cooking and art, how much soever he may be inclined to disbelieve it, is the sole object of his labour, and the more nearly his results approach to this, the more nearly they approach perfection. Thus, from the earliest times, instinct has taught him to add oil or butter to farinaceous substances, such as bread, which are naturally defective in this principle. The same instinct has taught him to fatten animals, with the view of procuring the oleaginous in conjunction with the albuminous principle, which compound he finally consumes, for the most part in conjunction with saccharine principles in the form of bread or vegetables. Even in the utmost refinements of his luxury and in his choicest delicacies, the same great principle is attended to, and his sugar and flour, his eggs and butter, in all their various forms and combinations, are nothing more nor less than disguised imitations of the great alimentary prototype, *milk*, as presented to him by nature."[p] It may be

[p] Consult also Dr. Prout's admirable *Bridgewater Treatise*, just published, in which will be found this and much other highly original and valuable matter.

worth reflecting, that children are particularly fond of saccharine substances, and dislike the oleaginous, at least fat.

More or less of common salt exists in the food of all animals. It is equally desired by the greater number, and many traverse immense tracts and encounter great difficulties to obtain it. Dr. Prout, I may mention, considers it, or the muriatic acid or chlorine which it affords, of the highest importance in the animal economy. How far a certain supply of other substances, as earths, metals, phosphorus, &c. from without is necessary, is not accurately known. Water is indispensable to vegetables and most animals.

Dr. Prout considers it as a general rule, subject, indeed, to many exceptions, that the food of organised beings is substances lower than themselves in the scale of organisation. Vegetables live chiefly on water and gases; and the animal or vegetable matters which also are their food, certainly must be in a state of entire decomposition. Some animals eat organised matter partly decomposed. The greater part live on animal or vegetable matter unchanged; and the animal matter is usually obtained from animals inferior in bulk or intelligence, — from animals with inferior powers of resistance. Man eats both animal and vegetable matter undecomposed, of infinite variety, all derived necessarily from beings inferior to himself. [q]

[q] M. Rastail, in a work published last year, at once profound, bold, and original, and containing the substance of various memoirs printed during the previous six years, entertains views very similar to those of Dr. Prout, though much more imperfect. He states, that proximate principles must be combined to become nutritious — that neither sugar nor gluten alone affords support, but that when combined they are alimentary. He offers the same objections to Dr. Magendie's conclusions respecting gum and other unazotised substances, which I have offered for many years. — *Nouveau Système de Chimie Organique, fondé sur des Méthodes Nouvelles d'Observation.* Par F. V. Rastail. Paris, 1833.

CHAP. II.

MASTICATION AND DEGLUTITION.

The food taken into the mouth, if solid, is reduced to a pulp by trituration and mixture with the fluids, and then passed into the stomach. The first process is termed *mastication* or *chewing;* the second, *deglutition* or *swallowing.*

" The lower jaw is the chief organ of mastication, and is supplied, as well as the upper, with three orders of teeth.

" With incisores, generally [a] scalpriform, for the purpose of biting off small pieces, and not placed in the lower jaw, as in other mammalia, more or less horizontally, but erect, — one of the distinctive characters of the human race.

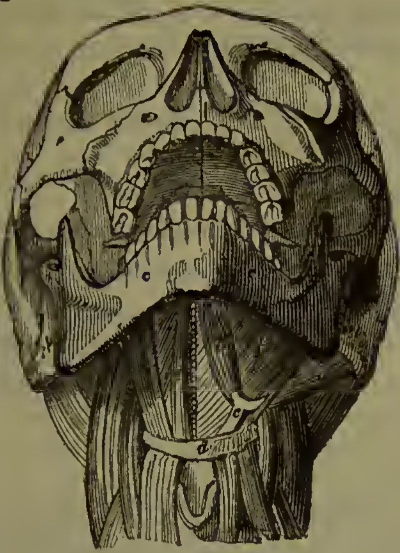
" With strong conical canine teeth, by which we divide hard substances, and which in man neither project beyond the rest, nor are placed alone, but lie closely and in regular order with the others.

" With molares of various sizes, adapted for grinding, and dif-

[a] " I say generally: for, without alluding to particular examples of their obtuseness, I may remark that I have found the crown of the incisors thick and obtuse in the skulls of most mummies. And since the more remarkable for this variety have resembled, in their general figure and appearance, the singular and never-to-be-mistaken physiognomy of the ancient Egyptians, observable in the idols, sarcophagi, and statues of ancient Egypt, it is probable that this peculiar form of the teeth, whether owing to diet or whatever else, was peculiar to the ancient Egyptians, and may be regarded as a national mark, or even as a characteristic by which true ancient mummies may be distinguished from those of late formation."

" I have written at large on this subject in the *Philos. Trans.* 1794. P. II. p. 184."

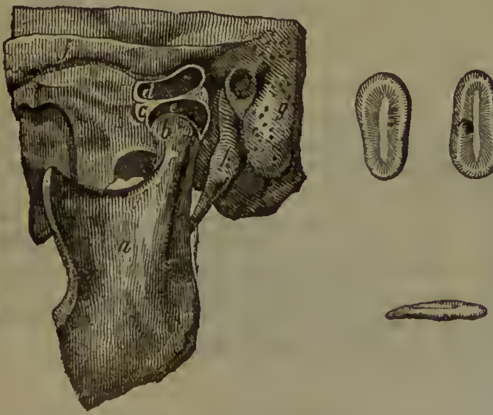
fering conspicuously from those of other mammalia, by possessing gibbous apices excessively obtuse.



The *four central* teeth in *both* jaws are the incisores: the *outer one* on *each* side in *both* is the canine: the *five outermost* on *each* side in *both* are the molares.

a, belly of the *digastric* arising at the root of the mastoid process of the temporal bone: *b*, belly arising below the symphysis of the lower jaw: *c*, tendon in which each ends: *d*, os hyoides, into which the tendon is inserted. If the os hyoides is fixed, the inner belly can lower the jaw: if the jaw is fixed, the os hyoides can be raised. *e*, genio-hyoideus: *f*, mylo-hyoideus.

" The lower jaw is connected with the skull by a remarkable articulation, which holds a middle rank between arthrodia and ginglymus; and, being supplied with two cartilaginous menisci of considerable strength, has easy motion in every direction." In other words, the condyles of the lower jaw are prevented from descending very deeply into the glenoid cavity; and are confined to vertical movements, by a cartilage which is hollow on each surface, and moveable, and permits the condyle to move from the glenoid cavity to a tubercle which stands before this, and thus to acquire still greater mobility.



a, outer part of the lower jaw: *b*, its condyle, pulled down from the glenoid cavity to show the joints: *c*, interarticular fibro-cartilage forming two menisci: *d*, upper synovial membrane: *e*, lower synovial membrane: *f*, zygoma: *g*, mastoid process: *h*, styloid process. The three other figures are a superior, an inferior, and a lateral, view of the interarticular cartilage.

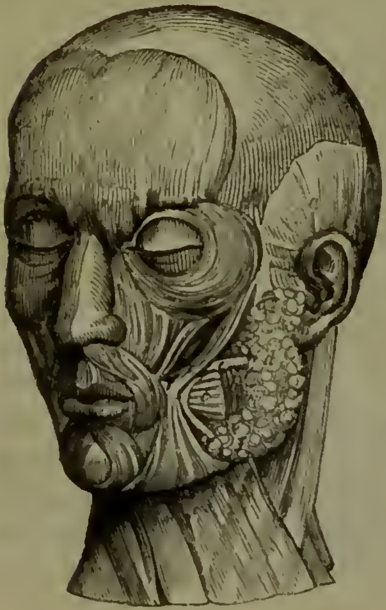
" The digaster, assisted somewhat by the genio-hyoidei and mylo-hyoidei muscles, draws the lower jaw down, when we open the mouth.

" The masseters and temporal chiefly raise it again when we bite off any thing, and are most powerfully contracted when we break hard substances.

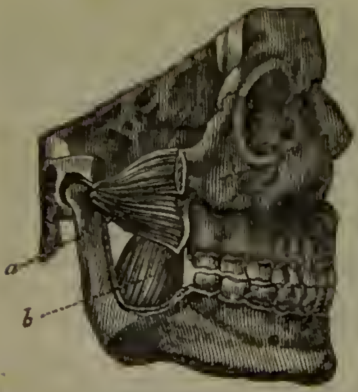
" Its lateral motions are accomplished by the internal and external pterygoid.

" The latter can also draw it forwards.

" Substances are retained, directed, and brought under the action of the teeth, by the buccinator, and by the tongue, which is very flexible and changeable in form.



a, temporal muscle, inserted by a tendon into the coronoid process of the lower jaw: *b*, masseter arising from the zygoma, and inserted into the angle of the lower jaw: *c*, buccinator, or great muscle of the cheek, the action of which is to lessen the cavity of the mouth, and draw the angle of the lips backwards. The mere inspection of the other muscles shows their action. *d*, the parotid gland: *e*, its duct: *f*, a portion of the sub-maxillary gland uniting with the parotid.



a, external pterygoid, arising from the pterygoid process and zygomato-temporal surface of the sphenoid bone, and the tuberosity of the os palati, and inserted into the front of the neck of the condyle of the lower jaw, and interarticular cartilage. *b*, internal pterygoid, arising from tho pterygoid fossa of the sphenoid bone, and from the pterygoid processes of the palate bone, and inserted within tho angle of the lower jaw.

"During mastication, there occurs a flow of *saliva*[b], which is a frothy fluid," consisting, according to Berzelius, of

Water - - - - - -	992.9
A peculiar animal matter - - -	2.9
Mucus - - - - - -	1.4
Alkaline muriates - - - -	1.7
Lactate of soda and animal matter -	0.9
Pure soda - - - - - -	0.2
	1000.0[c]

What Berzelius calls mucus, Dr. Thomas Thomson and Dr. Bostock regard as albumen. This mucus is insoluble in water, and, when incinerated, but not before, yields a large portion of phosphate of lime.[d]

According to an examination by Tiedemann and Gmelin, saliva, mixed with more or less mucus, consists of—

A peculiar matter termed salivary; osmazome; mucus;—all essential to its composition:

Sometimes a little albumen:

A little fatty matter, united with phosphorus:

Potass, united with acetic, phosphoric, sulphuric, hydro-chloric, and sulpho-cyanic acid;—all soluble salts:

A large quantity of phosphate, and a smaller of carbonate, of lime; a minute quantity of magnesia;—all three insoluble.

The solid contents amount to about $\frac{1}{25}$ per cent. The alkaline properties of saliva were before ascribed to a free alkali, and that alkali was supposed to be soda. In the dog the alkali is soda, very little potass being discoverable.[e]

M. Rastail remarks, that whatever other persons examine the saliva will have still other results, as different substances are mixed in it at different times, and names are given to the mixture the elements of which are not determined. He discovers that the

[b] "J. Barth. Siebold, *Historia Systematis Salivalis*. Jen. 1797. 4to."

[c] J. Berzelius, *Medico-Chirurgical Transactions*, vol. iii. p. 242.

[d] The tartar of the teeth arises from its gradual decomposition upon them, and consists, according to Berzelius, of

Earthy phosphates - - -	79.0
Undecomposed mucus - - -	12.5
Peculiar salivary matter - - -	1.0
Animal matter soluble in muriatic acid -	7.5
	100.0

[e] *Die Verdauung nach Versuchen*, &c. By Fred. Tiedemann and Leopold Gmelin, Professors in the University of Heidelberg.

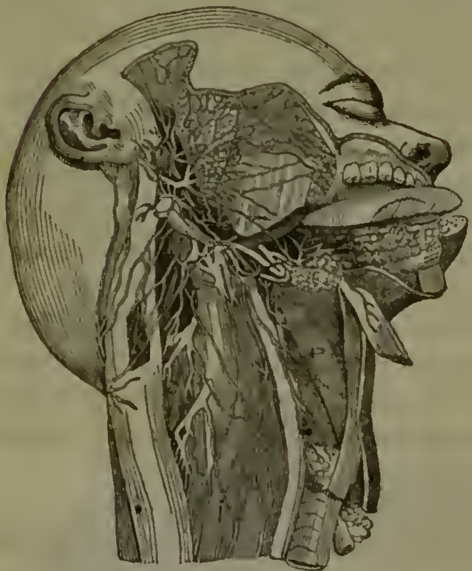
mucous membranes are constantly shedding and renewing, like the epidermis, from their cells successively shrivelling; and that saliva taken before breakfast, and examined with the microscope, presents such membranous particles, which are the animal matter mentioned by chemists, and soluble only in hydrochloric (muriatic) acid. He adds, that, besides muriate of soda, it contains muriate of ammonia; and as to the lactates, he proves that lactic acid is only a combination of albumen and acetic acid. The quantity of ammonia, salts, and membranous particles varies, and is much greater before breakfast. He considers the saliva to be an albuminous solution, mixed with membranous fragments and salts, which affect its solubility in water.[f]

" The saliva flows from three orders of conglomerate glands, placed laterally and interiorly with respect to the lower jaw.

" The *parotids*[g] are the largest, and pour forth the saliva behind the middle molares of the upper jaw, through the Stenonian ducts:[h]

" The *submaxillary*[i], through the Whartonian:[k]

" The *sublingual*[l], — the smallest, through the numerous Rivinian.[m]



a, parotid gland: *b*, parotid duct: *c*, submaxillary gland: *d*, submaxillary duct: *e*, sublingual gland.

[f] l. c., p. 454. sq.

[g] " See De Courcelles, *Icones Musculorum Capitis*, tab. I. *g*. *h*."

[h] " Stenonis, *Observationes Anatomicæ*, p. 20."

[i] " De Courcelles, l. c. tab. II. *t*. *t*."

[k] " Wharton, *Adenographia*, p. 120."

[l] " De Courcelles, tab. V. *g*. *g*. *g*."

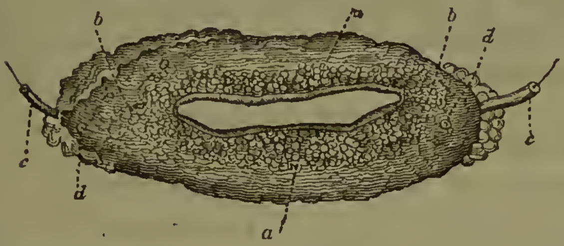
[m] " Rivinus, *De Dyspepsia*. Lips. 1678. 4to.
Aug. Fr. Walther, *De Lingua Humana*, ib. 1724. 4to."

"The excretion of saliva, amounting, according to the arbitrary statement of Nuck [n], to a pound in twelve hours, is augmented by stimuli and by mechanical pressure, or, if the term may be allowed, emulsion.

"The latter cause, greatly favoured by the situation of the parotids, at the articulation of the jaws, occurs when we chew hard substances, which thus become softened.

"The former occurs when acrid substances are taken into the mouth, which are thus properly diluted; or arises from imagination, as when the mouth waters during the desire for food.

"The mucus of the labial and buccal glands [o], and of the



Inner part of lips. *a a*, labial glands: *b*, buccal glands: *c c*, parotid ducts: *d d*, their orifices.

tongue, as well as the moisture which transudes from the soft parts of the mouth, is mixed with the saliva.

"The mixture of these fluids with a substance which we are chewing, renders it not only a pultaceous and easily swallowed bolus, but likewise prepares it for further digestion and for assimilation.

"The mechanism [p] of deglutition, although very complicated, and performed by the united powers of many very different parts, amounts to-this:—the tongue being drawn towards its root, swelling and growing rigid, receives the bolus of food upon its dorsum, which is drawn into a hollow form. The bolus is then rolled into the isthmus of the fauces, and caught with a curious and rather violent effort by the infundibulum of the pharynx, which is enlarged and in some measure drawn forward to receive it. The three constrictores [q] muscles of the pharynx drive it into the œsophagus. These motions are all per-

n "Nuck, *Sialographia*, p. 29. sq."

o "De Courcelles, l. c. tab. IV. *e. e. e.*"

p "Fr. Bern. Albinus, *De Deglutitione*. LB. 1740. 4to.
P. J. Sandifort, *Deglutitionis Mechanismus*. Lugd. Batav. 1805. 4to."

q "Eustachius, tab. XLII. fig. 4. 6.
Santorini, *Tab. Posthum.* VI. fig. 1.
B. S. Albinus, *Tab. Musculor.* XII. fig. 23, 24."

formed in very rapid succession, and require but a short space of time.

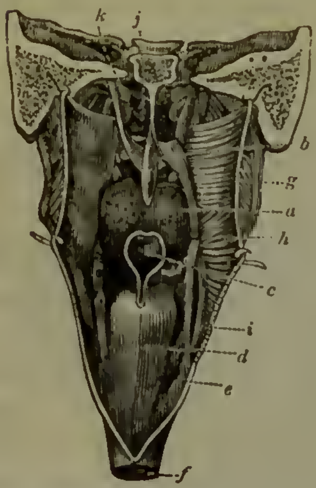
"Nature has provided various contrivances for opening and securing this passage.[r]

"The important motion of the tongue is regulated by the os hyoides.

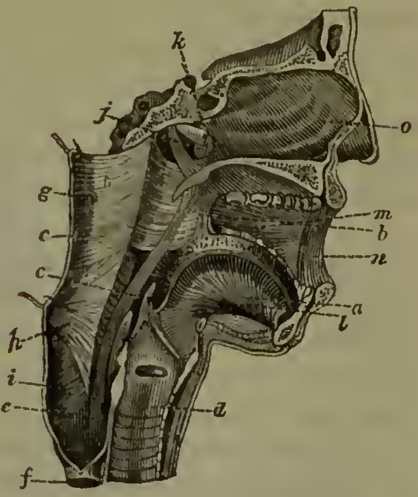
"The smallest particle of food is prevented from entering the nostrils or Eustachian tubes, by means of the soft palate[s], which, as well as the uvula suspended from its arch, and whose use is not clearly understood, is extended by muscles of its own, and closes those openings.[t]

"The tongue protects the glottis, for the larynx at the moment of deglutition is drawn upwards and forwards, and in a manner concealed under the retracted root of the tongue, and applied to the latter in such a way, that the glottis, being also constricted, and protected by the epiglottis, is most securely defended from the entrance of foreign substances." The glottis,

POSTERIOR VIEW.



LATERAL VIEW.



Posterior and lateral views of the throat. *a*, the tongue: *b*, palato-staphyline muscles, forming the uvula: *c*, epiglottis: *d*, larynx: *e*, pharynx: *f*, beginning of œsophagus: *g*, constrictor superior of pharynx turned back: *h*, constrictor medius: *i*, constrictor inferior: *j*, posterior opening of nostrils: *k*, opening of Eustachian tube: *l*, genio-glossus muscle: *m*, buccinator: *n*, orbicularis labiorum: *o*, cavity of the nostrils.

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[r] "J. C. Rosenmüller, *Icones Chirurgico-Anatomicæ.* Fasc. 1. Vinar. 1805. fol."

[s] "Littre, *Mém. de l'Acad. des Sc. de Paris,* 1718. tab. xv."

[t] "Santorini, *Tab. Posthum.* IV—VI. fig. 2. — and VII.
B. S. Albinus, *Tab. Musculor.* XII. fig. 11. 27, 28."

however, when sound, may be sufficiently closed by the transverse and oblique arytænoid muscles, independently of the epiglottis. Dr. Magendie says that he saw two persons perfectly destitute of epiglottis, who always swallowed without difficulty.[u] Targioni also met with one, and in that case neither deglutition nor speech was impaired.[x]

" Deglutition is facilitated by the abundance of mucus which lubricates these parts, and which is afforded not only by the tongue, but by the numerous sinuses[y] of the tonsils and muciparous cryptæ of the pharynx.

" The *œsophagus*, through which the food must pass previously to entering the stomach, is a fleshy canal, narrow and very strong, mobile, dilatable, very sensible, and consisting of coats resembling, except in thickness, the coats of the other parts of the alimentary canal.[z]

" The external coat is muscular, and possesses longitudinal and transverse fibres.

" The middle is tendinous, lax, and more and more cellular towards each of its surfaces, by which means it is connected with the two other coats.

" The interior is lined, like all the alimentary tube, with an epithelium analogous to cuticle, and is lubricated by a very smooth mucus.

" This canal receives the approaching draught or bolus of food, contracts upon it, propels it downwards, and, in the case of the bolus, stuffs it down, as it were, till it passes the diaphragm and enters the stomach."

Professor Hallé observed in a woman, the interior of whose stomach was exposed by disease, that the arrival of a bolus of food in the stomach was followed by an eversion of the mucous membrane of the œsophagus into it, as we notice in the case of the rectum when a horse has finished discharging its fæces.[a]

[u] Magendie, *Précis Elément.*

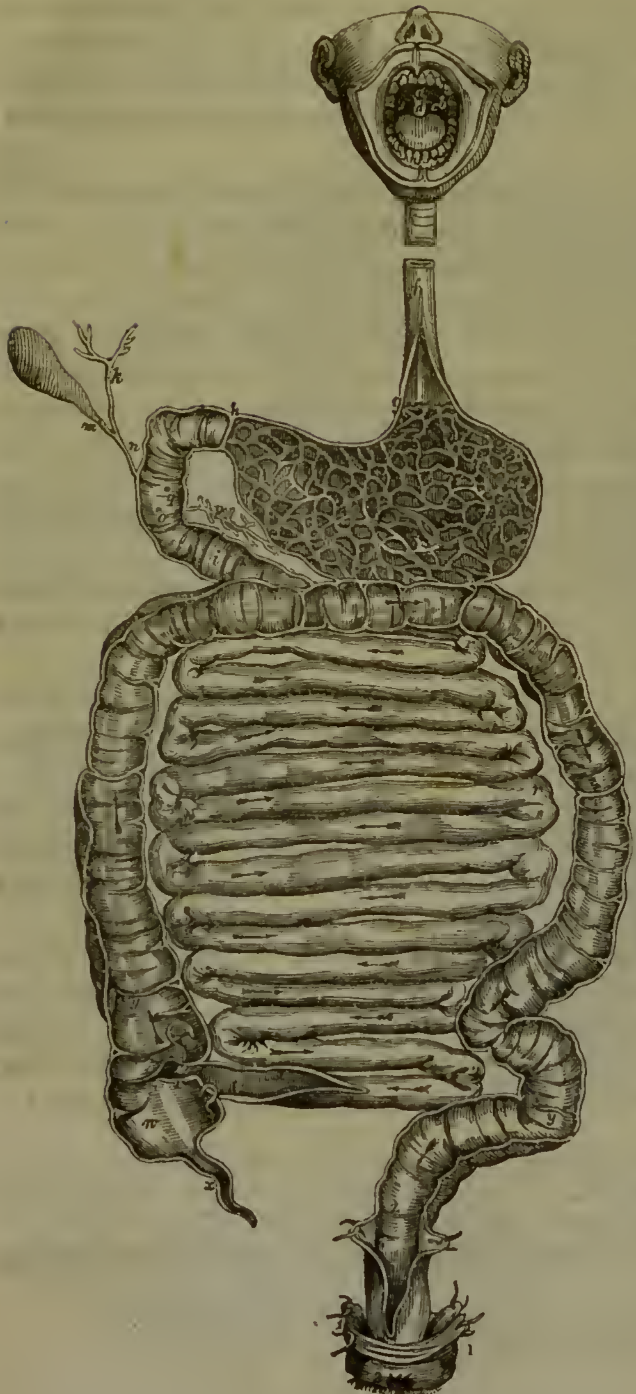
[x] Morgagni, xxviii. 13.

[y] " B. S. Albinus, *Anotat. Acad.* l. III. tab. III. fig. 1. *n.*"

[z] " See Math. Van. Geuns, *Verhandelingen van de Maatschappye te Haarlem*, t. xi. p. 9. sq.

" Jan. Bleuland, *Observ. de Structura Œsophagi.* LB. 1785. 4to."

[a] Magendie, *Précis Elémentaire.*



a, soft palate: *b*, anterior pillars of soft palate: c, posterior pillars of soft palate. The space between them is called the fauces. *d*, uvula: *e*, upper part of trachea: *f*, œsophagus, the upper part having been cut away to shorten the drawing: *g*, cardia: *h*, pylorus, the space between *g* and *h* being the cavity of the stomach: *i i*, duodenum: *k*, hepatic duct: *l*, gall bladder: *m*, cystic duct: *n*, ductus communis choledochus, formed of the two: *o*, the opening of the choledochus into the duodenum: *p*, pancreatic duct; *q*, its opening into the duodenum, which here is distinct from that of the choledochus: *r*, jejunum: *s*, ilium: *t*, termination of ilium in cæcum: *u*, superior fold of valve of colon; *v*, inferior of ditto: *w*, cæcum: *x*, vermiform process: *y y*, colon: *z*, rectum: 1, part of levatores ani: 2, anus.

CHAP. III.

DIGESTION.

"The *stomach* is the organ of digestion. It exists, what cannot be affirmed of any other viscus, in, perhaps, all animals without exception; and, if the importance of parts may be estimated in this way, evidently holds the first rank among our organs.

"The human stomach[a] resembles a very large leathern bottle, is capable, in the adult, of containing three pints and upwards of water, and has two openings.

"The superior, called *cardia*, at which the œsophagus, folded and opening obliquely, expands into the stomach, is placed towards the left side of its fundus.

"The inferior, at which the right and narrow part of the stomach terminates, is called *pylorus*, and descends somewhat into the cavity of the duodenum.

"The situation of the stomach varies accordingly as it is in a state of repletion or depletion. When empty, it is flaccid, and hangs into the cavity of the abdomen, its greater curvature inclining downwards, while the pylorus, being directed upwards, forms, by doubling, an angle with the duodenum.[b]

"When full, the larger curvature is rolled forwards[c], so that the pylorus lies more in a line with the duodenum, while the cardia, on the contrary, is folded, as it were, into an angle and closed.

"The stomach is composed of four principal coats, separated by the intervention of three others, which are merely cellular.

"The *external* is common to nearly all the alimentary canal, and continuous with the omentum, as we shall presently mention.

"Within this, and united to it by cellular membrane, lies the *muscular* coat, which is particularly worthy of notice from being

[a] "Eustachius, tab. x. fig. 1, 2, 3.
Ruysch, *Thes. Anat.* ii. tab. v. fig. 1.
Santorini, *Tab. Posth.* xi."

[b] "Vesalius, *De c. h. Fabrica.* L. v. fig. 14, 15."

[c] "Id. l. c. fig. 2."

the seat of the extraordinary irritability of the stomach. It consists of strata of muscular fibres[d], commonly divided into three orders, one longitudinal and two circular (straight and oblique), but running in so many directions that no exact account can be given of their course.

" The third is the chief membrane. It is usually termed *nervous*, but improperly, as it consists of condensed cellular membrane, more lax on its surfaces, which are united, on the one hand, with the muscular, and, on the other, with the internal villous coat. It is firm and strong, and may be regarded as the basis of the stomach.

" The *interior* (besides the epithelium investing the whole alimentary canal), improperly called villous, is extremely soft, and in a manner spongy, porous, and folded into innumerable rugæ[e], so that its surface is more extensive than that of the other coats; it exhibits very small cells[f], somewhat similar to those larger cells which are so beautiful in the reticulum of ruminants.

" Its internal surface is covered with mucus, probably secreted in the muciparous crypts which are very distinct about the pylorus.

" The stomach is amply furnished with nerves[g] from each nervous system, whence its great sensibility, owing to which it is so readily affected by all kinds of stimuli, — whether external, as cold,—or internal, as food and its own fluids,—or mental; whence also the great and surprising sympathy between it and most functions of the system; to which sympathy are referable the influence of all passions upon the stomach, and of the healthy condition of the stomach upon the tranquillity of the mind.[h]

" The abundance and utility of the blood-vessels of the stomach are no less striking. Its arteries, ramifying infinitely upon the cellular membrane and glands, secrete the *gastric juice*, which would appear to stream continually from the inner surface of the stomach.[i]

" In its general composition this fluid is analogous to the saliva

[d] " Besides Haller, consult Bertin, *Mém. de l'Acad. des Sc. de Paris*, 1761."

[e] " Ruysch, *Thes. Anat.* ii. tab. v. fig. 2, 3, 4*."

[f] " See G. Fordyce, *On the Digestion of Food*, p. 12. 59. 191."

[g] " Walter, *Tab. Nervor. Thorac. et Abdom.* tab. iv."

[h] " J. H. Rahn, *Mirum inter Caput et Viscera Abdominis Commercium.* Gotting. 1771. 4to.

Dit. Vegens, *De Sympathia inter Ventriculum et Caput.* LB. 1784. 4to.

Wrisberg, *Commentat. Societ. Scientiar. Gotting.* t. xvi."

[i] " Ever. Home, *Phil. Trans.* 1817. p. 347. tab. xviii. xix."

equally antiseptic, very resolvent [k], and capable of again dissolving the milk which it has coagulated.[l]

" Digestion is performed principally by it. The food, when properly chewed and subacted by the saliva, is dissolved [m] by the gastric fluid, and converted into the pultaceous chyme; so that most kinds of ingesta lose their specific qualities, are defended from the usual chemical changes to which they are liable, such as putridity, rancidity, &c., and acquire fresh properties preparatory to chylification.[n]

" This important function is probably assisted by various accessory circumstances. Among them, some particularly mention the *peristaltic motion*, which, being constant and undulatory, agitates and subdues the pultaceous mass of food.[o] The existence

k " Ed. Stevens, *De Alimentorum Concoctione*. Edinb. 1777. 8vo.
Laz. Spallanzani, *Dissertazioni di Fisica Animale e Vegetabile*. Modena. 1780. 8vo. vol. i."

l " Consult Veratti, *Comment. Instituti Bononiens*. tom. vi."
Seven grains of the inner coat of a calf's stomach were found by Dr. Young of Edinburgh to enable water poured upon it to coagulate 6857 times its weight of milk. Thomson's *System of Chemistry*, vol. iv. p. 596. ed. 6., and Fordyce *On Digestion*, p. 58.

m " Even the stomach itself, when deprived of vitality, has been found acted upon, and, as it were, digested, by it. See John Hunter, *On the Digestion of the Stomach after Death*. *Phil. Trans*. vol. lxii." This occurs particularly in the splenic portion, and a complete opening is sometimes made, with pulpy ragged edges, and the neighbouring organs with which the gastric juice comes in contact may be also corroded. It happens chiefly to persons and brutes who have been cut off in good health soon after taking food, and is observed also in vegetable feeders and fish. Some have ignorantly doubted this, and confounded it with softening from disease. Dr. Camerer of Stuttgard, in 1818, proved the accuracy of J. Hunter's opinion, by observing this softening to occur without putrefaction in brutes killed in good health, and putrefaction of the body to occur without softening of the stomach; and by ascertaining that the fluid, taken from a stomach which it had softened, produced the same change in another dead stomach to which it was transferred, but none upon another during life, though it immediately softened this stomach when the animal was killed, or both pneumogastric and trisplanchnic nerves were divided. This division alone produced no such effect. See Andral, *Précis d'Anatomie Pathologique*, t. ii. p. 86. sqq. A good paper, by Dr. Carswell, Professor of Morbid Anatomy in the London University, will be found in the *Journal Hebdomadaire*, Nos. 87. and 91., and the *Edin. Med. and Surg. Journ*, 1830.

n " Consult Ign. Doellinger, *Grundriss der Naturlehre des menschlichen Organismus*, p. 88."

o " Consult Wepfer, *Cicutæ Aquaticæ Historia et Noxæ*, in innumerable places."

of a true peristaltic motion in the stomach during health, is, however, not quite certain; indeed, the undulatory agitation of the stomach that occurs, appears intended for the purpose of driving the thoroughly dissolved portions downwards, while those portions which are not completely subacted are repelled from the pylorus by an antiperistaltic motion.

"The other aids commonly enumerated, are the pressure on the stomach from the alternate motion of the abdomen, and the high temperature maintained in the stomach by the quantity of blood in the neighbouring viscera and blood-vessels, which temperature was at one time supposed to be of such importance, that the word coction was synonymous with digestion."

It was once imagined that fermentation, and once that trituration, was the cause of digestion, but, as neither can produce the same effects on food out of the body that occur in the stomach, these opinions fell to the ground. Besides, no signs of fermentation appear when digestion is perfect; and food, either defended from trituration by being swallowed in metallic spheres perforated to admit the gastric juice[p], or immersed in gastric juice out of the body[q], is readily digested.

[p] The Abbe Spallanzani and Dr. Stevens made such experiments upon brutes: but the latter experimented upon a man also, who was in the habit of swallowing stones and rejecting them, and who of course found no difficulty in doing the same with metallic balls.

[q] Experiments of this kind were made by Spallanzani, who procured the gastric juice by causing hungry animals to vomit, or by introducing a sponge into the stomach. But still more marked results were lately obtained in the case of a lad who had a fistulous opening from the stomach, in consequence of a wound through which, by means of a hollow bougie and elastic bottle, gastric juice was procured at pleasure. A portion of beef was introduced into the stomach on a thread and withdrawn for comparison, at the same time that a similar portion was plunged into a phial of gastric juice, the temperature of which was kept steadily in a sand-bath at 100°, — the degree of the stomach's temperature, ascertained by the introduction of a thermometer. The portion in the phial became completely dissolved, though more slowly than that in the stomach; probably from the latter being supplied with a succession of fresh gastric juice, and freely exposed to it by motion; for the action of the fluid is only on the surface, and a portion of chicken placed in a phial of gastric juice, for a similar experiment, was more quickly acted upon if agitated. The gastric juice, when first obtained, was almost as clear as water, and its antiseptic power was shown by the solutions of beef and chicken remaining a whole autumnal month without fœtor or sour taste. *American Medical Recorder*, January, 1826. Spallanzani and others found, that if gastric juice is applied to putrescent matter, it removes the fœtor and suspends putrefaction.

"To determine the time requisite for digestion is evidently impossible, if we consider how it must vary according to the quality and quantity of the ingesta, the strength of the digestive powers, and the more or less complete previous mastication.

"During health, the stomach does not transmit the digestible parts of the food before they are converted into a pulp. The difference of food must therefore evidently cause a difference in the period necessary for digestion.[r] It may, however, be stated generally, that the chyme gradually passes the pylorus in between three and six hours after our meals."

"The *pylorus*[s] is an annular fold, consisting, not like the other rugæ of the stomach, of merely the villous, but also of fibres derived from the nervous and muscular, coats. All these, united, form a conoidal opening at the termination of the stomach, projecting into the duodenum, as the uterus does into the vagina, and, in a manner, embraced by it."

The digestive process does not go on equally through the whole mass of food, but takes place chiefly where this is in contact with the stomach, and proceeds gradually from the surface to the centre of the mass; so that the food at the centre is entirely different in appearance from that at the surface, and, as soon as a portion is reduced to a homogeneous consistence, it passes into the duodenum without waiting till the same change has pervaded the whole.[t]

Dr. Prout considers the *solution* of the food to be a common chemical process, and to depend principally upon the *combination* of water with the alimentary substance by means of the gastric juice. He has shown that this part of the functions of the stomach is quite distinct, and may exist or be absent independently of the *assimilating* process. Thus, in some forms of dyspepsia, the solvent powers of the stomach are almost entirely suspended, so that the patient, though he may be able to assimilate pulpy matters, is quite unable to digest any thing solid; while in diabetes, the solvent power of

[r] "Consult J. Walaeus, *De motu Chyli*, p. 534. LB. 1651. 8vo."

[s] "H. Palm. Leveling, *Dissert. sistens Pylorum, &c.* Argent. 1764. 4to. Reprinted in Sandifort's *Thes.* vol. iii."

[t] Dr. Prout, in *The Annals of Medicine and Surgery*, Lond. 1817., also in Thomson's *Annals of Philosophy*, 1819.

Dr. Wilson Philip, *An Experimental Inquiry into the Laws of the Vital Functions, &c.* 1826. p. 121. sqq. 3d edit. Dr. Philip published subsequently to Dr. Prout's first paper.

the stomach is often inordinately increased, and every article dissolved as soon as swallowed.[u]

Dr. Prout points out that hydrogen and oxygen *essentially* exist in many animal and vegetable proximate principles in the proportions which form water; in fact, that water essentially constitutes a part of them. This *essential* water is distinct from that which is accidental and makes the substance moist or fluid. If a large portion of water enters into their composition, the compound is *weaker* and *more easily decomposed.* Thus cane sugar consists of fifty-four parts of carbon with seventy-two of water: the weak sugar of honey consists of fifty-four parts of carbon with one hundred and eight of water. We cannot at pleasure lessen or augment the quantity of this essential water, and so alter the strength of the compound. The same holds in regard to the influence of water in all organised bodies. Thus strong, fixed, and solid oils have a very small constituent portion of water, and a large proportion of olefiant gas; while alcohol, the weakest form of the oily principle, perfectly soluble in water, contains more weight of water than half the weight of the olefiant gas.

Dr. Prout contends that the first stage of digestion is the solution and reduction of the proximate principles of various substances, by means of water and the muriatic acid of the stomach, to their weakest condition, — to that condition in which they are the most easily decomposed and brought into new combinations. The effect of good cookery is to facilitate this reduction of the proximate principles in the stomach to the weaker form;[x] for although we cannot by art make a weak compound strong (except, indeed, by lessening the water, incidentally moistening or dissolving it,) we are able in some measure to make a

[u] *Bridgewater Treatise*, by Dr. Prout.

[x] Continental cookery is superior to ours for weak stomachs, as far as it reduces substances to a pulp; but in the use of so much pure oil and pure sugar it is injurious, Dr. Prout remarks, to weak stomachs. For nature does not furnish sugar, starch, &c. or oil pure, but in combination. The purer we employ them, and especially those which are crystallizable, the more refractory is our food. Pure sugar, pure alcohol, and pure oil, are much less easy to be digested by the *healthy* stomach than substances purely amylaceous, or than that peculiar condition or mixture of alcohol existing in natural wines; or than butter. In these forms, the assimilation of the saccharine and the oleaginous principles is comparatively easy. Prout, l. c. p. 507. sq.

strong compound weak. The substance of young animals consists generally of weaker compounds than that of old, and is therefore tenderer and easier of digestion. Besides this reduction to a weaker state, the articles of food in general are more or less dissolved in the stomach.

After the solution of the food and the reduction of its proximate principles to the weaker forms, the stomach possesses the power of conversion, or of changing the proximate principles of the food into others, so that a fluid, called chyle, of pretty uniform composition, is obtained from it. Thus, it would appear, that the various substances belonging to the classes of saccharine, albuminous, and oleaginous, are all convertible into each other, some out of the body, some only within it. The albuminous and oleaginous require little change; and although the saccharine must require more, we ought to remember that sugar spontaneously becomes alcohol out of the body, and that alcohol is merely an oleaginous substance of a weak kind, and therefore probably undergoes in the stomach a similar series of changes to those which, out of the body, convert it to alcohol.[y]

The cardiac portion of the stomach is the chief seat of digestion, and when a part of the food is tolerably digested it passes along the large curvature to the pyloric portion, where the process is completed. As the cardiac half is the great digesting portion, it is this half that is found sometimes to have been dissolved by the gastric juice after death; its contents are much more fluid than those of the pyloric half; and Dr. Philip, who by the dissection of about a hundred and thirty rabbits has been enabled to furnish the completest account of what goes on in the stomach, relates the case of a woman who had eaten and properly digested to the last, but whose stomach was ulcerated every where except at the cardiac end. Sir Everard Home says he found that fluids which had been drunk were chiefly contained in the cardiac portion, and, like many others, for upwards of a century and a half[z], that, if the body was examined early after death, the two portions of the stomach were frequently in fact divided by a muscular contraction.[a] Dr. Haighton observed the same

[y] Dr. Prout, l. c. p. 493. sqq.

[z] See Dr. Monro (Tertius), *Outlines of the Anatomy of the Human Body in its sound and diseased State*, vol. ii. p. 111. 1813.

[a] *Phil. Trans.* 1808.

hour-glass contraction in a living dog, and remarked the peristaltic motion to be much more vigorous in the pyloric half.[b]

Van Helmont asserted that the food becomes sour by digestion, but this was afterwards denied, and acidity said never to happen except in cases of disorder. Sir Gilbert Blane, many years ago, however, declared that he had "satisfied himself that there is such an acid (the *gastric*) by applying the usual tests to the inner surface of the stomach of animals. This property in ruminating animals," he added, "is confined to the digesting stomach."[c] Dr. Prout has discovered that the acid generated is the muriatic, both free and in combination with alkalies.[d] Tiedemann and Gmelin soon afterwards found the same thing, though without knowing, they assure us, Dr. Prout's discovery. They assert the clear ropy fluid of the stomach, or gastric juice, without food, to be nearly, or entirely, destitute of acidity, while the presence of food, or of the most simple stimulus to the mucous membrane, occasions it to become acid, and more so, according to the greater indigestibility of the food. The acid is very copious. They also assert the presence of acetic acid; but Dr. Prout believes this to be either the result of irritation or of disease, or occasionally to be derived from the aliment, and consequently to be neither necessary nor ordinary. The general change of the aliment in the stomach appears a greater or less approach to the nature of albumen, but Dr. Prout has been unable to detect true and perfect albumen there when none has been taken.

Brutes have been the subjects of these experiments; chiefly the rabbit, horse, dog, and cat.

Besides the labours of Dr. Prout, and of the professors of Heidelberg, a work has been published on all the subjects of chymification and chylification by MM. Leuret and Lassaigne, contradictory in many respects to the results of the others; but, knowing as I do the extreme accuracy of Dr. Prout in experimenting and deducing, and seeing that Tiedemann and Gmelin have bestowed infinite labour in repeating, varying, and extend-

[b] *Transactions of the Medical Society of London*, vol. ii. 1788. In the lion, bear, &c., the stomach is usually found divided by a slight contraction at its middle, and in some animals of the mouse kind by a slight elevation of its inner coat.

[c] *Transactions of a Society for the Improvement of Medical and Surgical Knowledge*, vol. ii. p. 138. sq.

[d] *Phil. Trans.* 1824.

ing their experiments, and have detailed all their proceedings, while the French writers merely give results, and appear to have bestowed far less pains, I must be excused for merely mentioning their work.[e]

The inspection of living animals shows, that, during chymification the mucous membrane of the stomach, and during chylification that of the small intestine, becomes strikingly red; and if an animal is killed during either process, this redness is seen in the corresponding portion of the coat.[f]

[e] *Recherches Physiologiques et Chimiques pour servir à l'Histoire de la Digestion.* Paris, 1825.

An immense number of curious facts respecting different articles of food, and many points on the subject of digestion, will be found in the German work, and a good history of opinions in the French.

[f] Andral, *Précis d'Anatomie Pathologique*, t. ii. P. i. p. 6.

In granivorous birds the food passes into the crop, and from this into a second cavity, from which it enters the gizzard, — a strong muscular receptacle, lined by a thick membrane, in which, instead of having been masticated, it is ground by means of pebbles and other hard bodies swallowed instinctively by the animal; hence true salivary glands do not exist about the mouth of birds, but abound in the abdomen, opening into the lower part of the œsophagus and into the crop and gizzard. In carnivorous birds, the gizzard is soft and smooth. The fluids of both crop and gizzard contain a free acid, according to Tiedemann and Gmelin, which is the muriatic or acetic.

Some graminivorous quadrupeds with divided hoofs have four stomachs, into the first of which the food passes when swallowed, and from this into the second. It is subsequently returned by portions into the mouth, chewed, and again swallowed, when, by a contraction of the openings of the two first stomachs, it passes over them into the third, and from this goes into the fourth. The process can be delayed at pleasure when the paunch is quite full. Some birds and insects also *ruminate*. The same chemists found the fluids of the two first stomachs alkaline, and of the third and fourth, acid. The stomachs of some insects and crustacea contain teeth. Some zoophytes are little more than a stomach, the food taken into it being chiefly dissolved and absorbed, and the refuse expelled at the orifice by which it had entered: others have several openings on the surface leading by canals that unite and run to the stomach, — a structure called by Cuvier, *mouth-root*. In regard to vegetables, it is not the whole root which absorbs, but the minute fibrous prolongations, which are called *spongioles*. Some roots are also reservoirs of nourishment. Between the most distinct kinds of stomach we see numerous intermediate varieties. The cardiac half of the interior of the stomach of the horse, for example, is covered by cuticle, and appears merely recipient, while the pyloric half is villous and digestive; and the state of the contents in each half is, therefore, very different: a link thus existing between such stomachs as the human and the ruminating.

Vomiting cannot occur unless the stomach have the resistance of the diaphragm and abdominal muscles, or of something in their stead. Above a century and a half ago, enquirers began to make the horrid experiment of giving an emetic to an animal, and, after the abdominal muscles were cut away, observing how fruitless were all the efforts of the stomach to reject its contents till they applied their hands in place of these muscles, when, the stomach being forced by the diaphragm against the resistance, vomiting was instantly accomplished. From these experiments, Bayle, Chirac, Schwartz, Wepfer, &c. inferred that vomiting could not occur without the assistance of the diaphragm and abdominal muscles. Haller, *Element. Physiol.* lib. xix. § xiv. Afterwards J. Hunter said, "We know that the action of vomiting is performed entirely by the diaphragm and abdominal muscles." *On certain Parts, &c.* p. 199. Again, on the other hand, Dr. Magendie finds that if the stomach is removed, and a pig's bladder substituted and connected with the œsophagus the retching induced by injecting tartarized antimony into the veins, causes the diaphragm and abdominal muscles to compress it sufficiently to expel its contents into the mouth. *Mémoire sur le Vomissement*, and *Précis Elémentaire.* The division of the par vagum, which supplies the stomach, was found by him, accordingly, not to prevent vomiting; whereas the division of the phrenic nerves, which supply the diaphragm, greatly impedes it.

But Dr. Haighton, one of those who have experimented on the subject, declares that the division of the par vagum did prevent vomiting in two experiments which he made. (*Memoirs of the Lond. Med. Society*, vol. ii.) Dr. Haighton observed the peristaltic action of the stomach to grow gradually fainter as sickness continued, and at length to be inverted, although alone insufficient to effect vomiting; and he concluded that vomiting resulted from the operation of the stomach on the one hand and of the abdominal muscles and diaphragm on the other. He remarked that a quantity of air was swallowed previously to the discharge, and the stomach is thus distended and brought more under the influence of the diaphragm and abdominal muscles.

"In vomiting, the muscles of the cavity of the abdomen act, in which is to be included the diaphragm; so that the capacity of the abdomen is lessened, and the action of the diaphragm rather raises the ribs, and there is also an attempt to raise them by their proper muscles, to make a kind of vacuum in the thorax, that the œsophagus may be rather opened than shut, while the glottis is shut so as to let no air into the lungs. The muscles of the throat and fauces act to dilate the fauces, which is easily felt by the hand, making there a vacuum, or what is commonly called a suction." J. Hunter, *Observations on certain Parts of the Animal Economy.*

It is generally accompanied by more or less of a peculiar sensation in the stomach, called nausea. This frequently exists alone, and sometimes in a high degree; but where it increases to a certain amount, it usually ends in vomiting. During nausea the pulse is small, the temperature low, the face pale, and the head giddy, and a large quantity of fluid is secreted in the mouth and fauces. It is excited by disgust, certain articles, pain, sympathy of the stomach with other organs not in health, by general derangement or disease of the stomach, by turning round, swinging, or the motion of a ship, and from the latter cause takes its name,—*ναῦς* (a ship).

The stomach has been called the grand centre of sympathy. Its sympathies are great, but there is no reason for considering it the *centre* of sympathy. Blows upon the head or testicle, and diseases of the kidney and uterus, nay, the mere pregnant state of the latter, severe pain in any part, or a disgusting sight, will often cause vomiting. Any depressing passion deranges the stomach, but anxiety is a common source of stomach complaints, although the stomach generally bears the whole blame, and is in vain drugged and dieted, or want of exercise or great mental occupation is regarded as the cause, while the anxiety is overlooked. Pleasurable mental exertion, " constant occupation without care," must be very excessive to injure the stomach.

The stomach itself, except as far as its inner surface is very extensive and sensible and therefore highly adapted for the influence of ingesta, appears, on the whole, to affect other organs, by mere sympathy, far less than it is influenced by them. The immediate debility and breathlessness occasioned by a blow on the stomach is, however, well known. I saw a person gradually sink, and die at the end of a few days from this cause, and nothing was detected after death.

The removal of a piece of the par vagum, or the destruction of that part of the brain with which it is connected, or of a considerable part of the spinal marrow, puts a stop, not to the muscular action of the stomach, or to its circulation, but to the secretion of gastric juice and to digestion, according to Le Gallois, *Sur le Principe de la Vie*, and many former writers; and Dr. Philip, who is confirmed by several others, declares that the removal of a portion of the nerve impairs digestion much more than mere division, and that the application of galvanism to the stomach restores digestion; and MM. Leuret and Lassaigne declare, that after the division of the par vagum, and even the removal of six inches of each nerve, digestion proceeds as before, the only effect being the paralysis of the sphincter of the cardia. I should remark, that Mr. Brodie and Dr. Magendie found even digestion uninfluenced, if the division was made, not in the neck, but close to the stomach. *Phil. Trans.* 1814. *Précis Elémentaire*, t. ii. p. 103.

CHAP. IV.

OF THE PANCREATIC JUICE.

" The chyme, after passing the pylorus, undergoes new and considerable changes in the duodenum [a], a short but very remarkable portion of the intestine, before the nutrient chyle is separated. To this end, there are poured upon it various secreted fluids, the most important of which are the bile and pancreatic juice.

" Of these we shall treat separately, beginning with the pancreatic fluid, because it is closely allied both in nature and function to the saliva and gastric juice already mentioned.

" Although it is with difficulty procured pure from living and healthy animals, all observations made in regard to it establish its close resemblance to the saliva. At the present day, it would scarcely be worth while to mention the erroneous hypotheses of Franc. Sylvius [b] and his followers — Regn. De Graaf [c], Flor. Schuyl [d], and others, respecting its supposed acrimony, long since ably refuted by the celebrated Pechlin [e], Swammerdam [f], and Brunner [g], unless they afforded a salutary admonition, how fatal the practice of medicine may become, if not founded on sound physiology.

" The source of this fluid is similar to that of the saliva. It is the *pancreas* [h], — by much the largest conglomerate gland in the system, excepting the breasts," being about three times heavier than all the salivary glands together [i], " and extremely analogous to the

[a] " Laur. Claussen, *De Intestini Duodeni situ et nexu.* Lips. 1757. 4to. Reprinted in Sandifort's *Thes.* vol. iii.

And his *Tabulæ Intestini Duodeni.* LB. 1780. 4to."

[b] " *De Chyli a fæcibus alvinis secretione.* LB. 1659. 4to."

[c] " *De succi Pancreatici Natura et Usu.* ib. 1664. 12mo."

[d] " *Pro Veteri Medicina.* ib. 1670. 12mo."

[e] " *De Purgantium Medicamentorum Facultatibus.* ib. 1672. 8vo."

[f] " *Observationum Anatomic. Collegii privati Amstelodamens.* P. ii. *in quibus præcipue de piscium pancreate ejusque succo agitur.* Amst. 1673. 12mo."

[g] " *Experimenta nova circa pancreas.* Amst. 1683. 8vo."

[h] " Santorini, *Tab. Post.* xiii. fig. 1."

[i] Marherr, *Prælectiones in* Her. Boerhaave, *Instit. Med.* t. i. § ci.

salivary glands in every part of its structure, even in the circumstance of its excretory ducts arising by very minute radicles and uniting into one common duct, which is denominated, from its discoverer Wirsüngian.

" This duct penetrates the tunics of the duodenum, and supplies the cavity of this intestine with a constant stillicidium of pancreatic juice."[k]

Pancreas, *a*, pancreatic duct: *b*, choledochus : *c*, junction of the two and their termination in the duodenum : *d*, a portion of the duodenum divided.

The quantity of the pancreatic juice cannot be accurately ascertained. It is, no doubt, produced copiously during chylification, and cannot be expected to flow readily at other times, or naturally under the torments of an experiment.

" The excretion of this fluid is augmented by the same causes which affect that of the saliva,— pressure and stimulus.

" By the former it is emulged, whenever the stomach lies in a state of repletion upon the pancreas.

" The stimuli are the fresh and crude chyme entering the duodenum, and the bile flowing through the opening common to it and the pancreatic fluid."

The use of the pancreatic juice is unknown, but Tiedemann and Gmelin conceive that it animalises the unazotised principles of vegetable food. The organ is certainly much larger proportionately in herbivorous than in carnivorous animals. They assign the same purpose to the saliva.

[k] Mr. Kiernan states, that in some subjects the internal surface of the duct is studded with mucous follicles; whereas none are ever found in the ducts of the parotid or submaxillary glands. *Phil. Trans.* 1833. p. 728.

The pancreatic juice, at least in the sheep, according to them, has twice as much solid contents as the saliva, and conversely a large quantity of albumen and fatty matter with a small quantity of salivary matter and mucus; is neutral, or has only a little alkaline carbonate, and no sulpho-cyanic acid.

The pancreas exists in all the mammalia, birds, reptiles, and fishes.

Brunner, about 150 years ago, removed almost the whole pancreas from dogs, and tied and cut away portions of the duct; and they lived apparently as well as before. From one he was not contented with removing the spleen at one time and the pancreas at another, after which the poor animal *pancratice valebat;* but, to render it celebrated for experiments, he on a third occasion laid bare the intestines and wounded them for an inch and a half, sewed up the wound, made a suture in the abdominal parietes so badly that the intestines were found hanging out on the ground one morning, purple and cold, and then allowed the animal to lick the wound into healing. He also performed the operation for aneurysm in the artery of its hind leg, and paracentesis of its chest, injecting a quantity of milk into the pleura and pumping it out again. This even was not enough for the gentle Brunner; he gave the dog such a dose of opium, when it had recovered from the operation on the spleen, that it was seized with tetanus. But this also it got the better of, and lived upwards of three pleasant months with its master, "gratus mihi fuit hospes," after all these indulgences, and was at last lost in a crowd; stolen, no doubt, because "celebris ab experimentorum multitudinem, — vivum philosophiæ experimentalis exemplum, et splene mutilus, variis cicatricibus notabilis.". Brunner offered any money for it again, but to no purpose. (p. 6. 13.)

CHAP. V.

THE BILE.

"The bile is secreted by the *liver*[a]—the most ponderous and the largest of all the viscera, especially in the fœtus[b], in which its size is inversely as the age. The high importance of this organ is manifested, both by its immense supply of blood-vessels and their extraordinary distribution, as well as by its general existence, for it is not less common to all red-blooded animals than the heart itself.[c] It exists also in invertebral animals with colourless blood, wherever a heart and blood-vessels are present.

"The substance of the liver is peculiar, easily distinguished at first sight from that of other viscera, of well-known colour and delicate texture[d], supplied with numerous nerves[e], lymphatics (most remarkable on the surface)[f], biliferous ducts, and, what

[a] "Eustachius, tab. xi. fig. 3, 4.
Ruysch, *Thes. Anat.* ix. tab. iv.
Santorini, *Tab. Posth.* xi."

[b] "J. Bleuland, *Icon hepatis fœtus octimestris.* Traj. ad Rhen. 1789. 4to.
F. L. D. Ebeling, *De Pulmonum cum hepate antagonismo.* Gott. 1806. 8vo."

[c] "See Nic. Mulder's *Diss. de functione hepatis, in Disquisitione zootomica illius visceris nixa.* Lugd. Bat. 1818. 8vo."

[d] "In which, however, Autenreith discovers two substances, the one medullary and the other cortical. *Archiv. für die Physiol.* t. vii. p. 299.
Consult also J. M. Mappe's Dissertation, *De penitiori hepatis humani structura,* Tub. 1817. 8vo."

[e] "Walter, tab. iv."

[f] "Maur. v. Reverhorst, *De motu bilis circulari ejusque morbis,* tab. i. fig. 1, 2.
Ruysch, *Ep. Problemat.* v. tab. vi.
Werner and Feller, *Descriptio vasor. lacteor. atque lymphaticor.* Fascic. i. tab. iii. et iv.; although Fr. Aug. Walter finds fault with these plates, *Annot. Academic.* p. 191. sq.
Mascagni, tab. xvii. xviii."

these ducts arise from, blood-vessels[g], which are both very numerous and in some instances very large, but of different descriptions, as we shall state particularly.

" The first blood-vessel to be noticed is the *vena portarum* (or *portæ*), dissimilar from other veins, both in its nature and course. Its trunk is formed from the combination of most of the visceral veins belonging to the abdomen, is supported by a cellular sheath called the capsule of Glisson[h], and, on entering the liver, is divided into branches which are subdivided more and more as they penetrate into the substance of the organ, till they become extremely minute, and spread over every part. Hence Galen compared this system to a tree whose roots were dispersed in the abdomen, and its branches fixed in the liver.[i]

" The other kind of blood-vessels belonging to the liver, are branches of the *hepatic artery*, which arises from the cœliac, is much inferior to the vena portæ in size, and in the number of its divisions, but spreads by very minute ramifications throughout the substance of the organ.

" The extreme divisions of these two vessels terminate in true veins, which unite into large venous trunks running to the *vena cava inferior*.

" These extreme divisions are inconceivably minute and collected into very small glomerules[k], which deceived Malpighi into the belief that they were glandular acini, hexagonal, hollow, and secretory.[l]

" From these glomerules arise the *pori biliarii*—very delicate ducts, secreting the bile from the blood, and discharging it from the liver through the common hepatic duct, which is formed from their union."

Such is the account of the anatomy of the liver, given by most writers as well as Blumenbach. But Dr. Müller, Professor at Bonn,[m] declares that he has discovered all glands, and the

[g] " See Haller, *Icones Anat.* Fascic. ii. tab. ii."

[h] " Glisson, *Anatomia Hepatis*, p. 305. sq. 1659."

[i] " *De Venarum Arteriarumque dissectione*, p. 109. Opera. Basil. 1562. Cl. i."

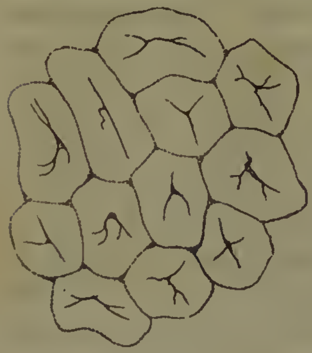
[k] " Nest. Maximcow. Ambodick, *De Hepate*. Argent. 1775. 4to."

[l] " *De viscerum structura*, p. 11. Lond. 1669."

[m] *De Glandularum secernentium Structura penitiori, earumque prima Formatione in Homine atque in Animalibus*. Lipsiæ. 1830.

liver among the rest, to be mere ducts, beginning from blind extremities, and having blood-vessels ramifying on their parietes. The *biliferous ducts,* therefore, are not continuous, as Blumenbach says, with blood-vessels; and Haller remarks, that no one ever discovered such a continuation: but their fluids must be poured into them from their inner surface, as fluids are secreted into canals lined by mucous membrane.

Mr. Kiernan has recently published a most elaborate and original paper upon the structure of the liver, and states, — That the extreme subdivisions of the *hepatic artery* all terminate in, or become, veins that run into the branches of the vena portæ; so that this vein originates not only from the veins of the other abdominal viscera, but also in the liver itself, as Ferrein pointed out a century ago, and the artery has no termination in either biliferous ducts or hepatic veins, and is destined for nutrition, not for the secretion of bile. — That the subdivisions of the *vena portæ* (except, I presume, those which become secreting vessels in the coats of the minutest biliferous ducts, and pour forth fluid from their extremities upon the inner surface of those ducts, unless indeed the fluid pass through pores in their sides,) all terminate in, or become, the hepatic veins: — That the minutest biliferous ducts, the subdivisions of the vena portæ, and the hepatic veins, are conglomerated into minute masses or lobules, which Wepfer first discovered in the pig, surrounded, except at their base, with a capsule of cellular membrane, that is a prolongation of Glisson's capsule and the proper capsule of the liver, and supplied with minute arteries, and probably nerves and absorbents; when there is much cellular membrane in the capsule, the lobules not being close together, but touching each other by two or three points only, and being more or less circular or oval;



when the reverse is the case, being closely compacted, and therefore angular: — That the branches of the vena portæ, after running between the lobules, and covering them (except at their bases) and freely anastomosing around them, so as to form a continued plexus throughout the liver, enter the lobules most minutely subdivided, and become hepatic veins, which unite into one large vessel in each process of every lobule, and then these large vessels run into one which passes down the centre of the lobule, and goes out at the base, so as to look like a stalk to the lobule. The veins formed from

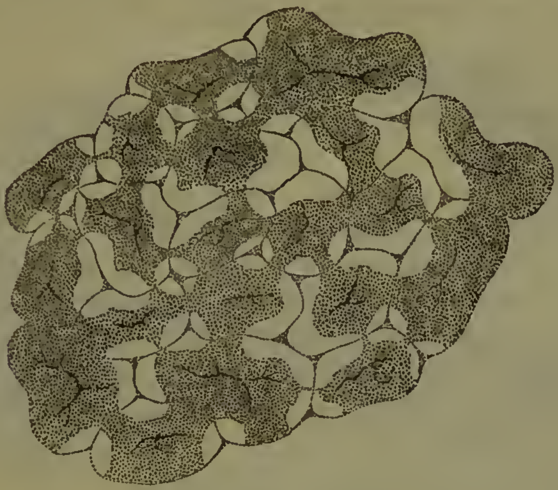
these run between the bases of the lobules and anastomose, and are called sublobular, to distinguish them from the hepatic veins within, which are called intralobular and do not anastomose, and from the portal branches without, which run between the other parts of the surface of the lobules, or rather in the capsules of the lobules, and are called interlobular and anastomose so freely.

The lobules are very sparingly supplied with arteries, while the biliferous ducts possess outside the lobules an abundance of them.

The minutest biliferous tubes form a reticulated plexus in each lobule, and unite into branches which leave it. These lobular biliary plexuses have much the appearance of cells, and deceived some into the belief of cells which give origin to ducts; and these Malpighi and others erroneously termed acini.

As the liver so abounds in venous blood, it is very liable to congestion; and any impediment to the exit of the blood from the hepatic veins, as in diseases of the chest, will cause it to accumulate in the large branches, then in the sublobular, the central hepatic vein of each lobule, the twigs which run to it, and at length in the central part of the lobular portal plexuses. If the congestion is not greater, the central portion of the

lobules becomes red, and the outer portion retains its usual yellowish colour. This appearance made Ferrein, and after him many others, believe that two substances exist in the liver, a red and a white; and it is the usual state after death. If the congestion is greater, it extends beyond the central portion of the plexuses of the portal veins in the lobules, even to the portal branches in the fissures, and the redness reaches the edge of the lobules for the greater part — except where the lobules are not quite in contact with each other; and the liver in this state is called a nutmeg liver.



When still greater, the whole of each lobule is red.

Congestion beginning in the vena portæ is very rare, and the outer portion of the lobules is then red, while the central, in which the hepatic veins lie, remains pale.[n]

" It has been disputed whether the bile is produced from arterial or venous blood.

" The former opinion[o] is countenanced by the analogy of the other secretions which depend upon arterial blood; nevertheless more accurate investigation proves that the greater part, if not the whole, of the biliary secretion is venous.

" With respect to arguments derived from analogy, the vena portæ, resembling arteries in its distribution, may likewise bear a resemblance to them in function. Besides, the liver is analogous

[n] *Phil. Trans.* 1833.

[o] " This has found an advocate in Rich. Powel, *On the Bile and its Diseases.* Lond. 1801. 8vo."

to the lungs, in which the great pulmonary vessels are intended for their function, and the bronchial arteries for their nourishment; and, if we are not greatly mistaken, the use of the hepatic artery is similar."

M. Simon informs us, that, after tying the hepatic artery in pigeons, the bile was secreted as usual; but after tying the vena portæ, none was produced.[p] A. Kaau found water injected into either the vena portæ or hepatic artery exude on the surface of the liver[q]; but this might be mere imbibition.

From the great abundance of twigs of the vena portæ which are distributed in the lobules, among the original biliferous or secreting ducts, and the extremely small number of arteries which enter the lobules, though they run plentifully upon the larger or excreting biliferous ducts, Mr. Kiernan infers that the bile is secreted from the blood of the vena portæ alone.

Two instances have occurred in London, of the vena portæ running, not to the liver, but immediately to the vena cava inferior. One is described by Mr. Abernethy[r], and the other is mentioned by Mr. Lawrence.[s] Mr. Kiernan has examined the preparation made from Mr. Abernethy's case, and found that the branches of the umbilical vein were open, and communicated with the hepatic artery, the blood of which, having become venous in the capillaries, must have found its way for secretion to the lobules by means of the ramifications of the umbilical vein, which was in truth, as it always is, the vena portæ, but arose in this case from the extremities of the hepatic artery alone, and not, as in ordinary cases, from them and the extremities of the arteries of the other abdominal viscera, by means of their veins, which unite to form what is termed properly the vena portæ.

In the mollusca, there is certainly no vena portæ, and the liver receives its blood from the aorta.

"The *bile* flows slowly, but constantly, along the hepatic duct. The greater portion runs constantly through the ductus communis choledochus into the duodenum, but some passes from the hepatic into the *cystic duct*, and is received by the gall-bladder, where it

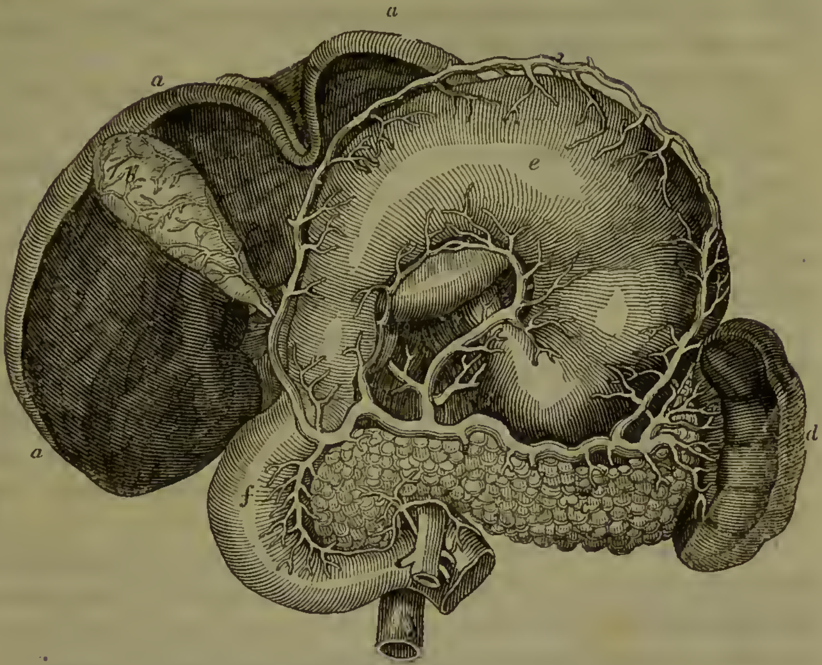
[p] *Edinburgh Journal of Medical Science*, No. i. p. 229. This effect of tying the vena portæ was long ago observed. See Sömmerring, *De C. H. Fabrica*, t. vi. p. 182.

[q] *Perspiratio dicta Hippocrat.* 563.

[r] *Phil. Trans* vol. lxxxiii.

[s] *Medico-Chirurgic. Trans.* vol. v. p. 174

remains for a short period, and acquires the name of *cystic bile.*[t]



The liver, gall-bladder, and stomach, raised.

a a a, liver; *b*, gall-bladder; *c*, pancreas; *d*, spleen; *e*, stomach; *f*, duodenum. See also the cut at the end of Chap. II.

" The *gall-bladder* is an oblong sac, nearly pyriform, adheres to the concave surface of the liver, and consists of three coats :—

" An *exterior*, not completely covering it, derived from the peritonæum.

" A *middle*, called nervous, and, as in the stomach, intestines, and urinary bladder, the source of its firmness and tone.

" An *interior*[u], which may be, in some measure, compared to

[t] " In the ox and other brutes there are peculiar *hepato-cystic* ducts, which convey the bile directly from the liver to the gall-bladder.

See *Observat. Anatom. Collegii privati Amstelodamens.* P. i. Ams. 1667. 12mo. p. 16. fig. 7.

Also Perrault, *Essais de Physique,* t. i. p. 339. tab. ii.

Some have inconsiderately allowed them also in the human subject: v. c. De Haen *Ratio medendi contin.* P. ii. p. 46. sq. tab. x. fig. 1.

Also Pitschel, *Anat. und chirurg. Anmerk.* Dresd. 1784. 8vo. tab. i.

Consult more at large, R. Forsten, *Quæstiones selectæ physiologicæ.* Lugd. Batav. 1774. 4to. p. 22."

[u] " Ruysch, *Epist. problem. quinta.* Tab. v. fig. 3."

the inner coat of the stomach, as it contains a network of innumerable blood-vessels, abounds in mucous glands[x], and is marked by rugæ[y], which occasionally have a beautifully cancellated and reticulated appearance.

"Its cervix is conical, terminates in the cystic duct, is tortuous, and contains a few falciform valves.[z]

"The bile which has passed into the gall-bladder is retained until, from the reclined or supine posture of the body, it flows down from it spontaneously, or is squeezed[a] out by the pressure of the neighbouring jejunum, or ileum, or of the colon when distended by fæces.

"The presence of stimuli in the duodenum may derive the bile in that direction.

"The great contractility of the gall-bladder, proved by experiments on living animals, and by pathological phenomena, probably assists the discharge of bile, especially when this fluid has, by retention, become very stimulating.

"For the cystic bile, though very analogous to the hepatic, becomes more concentrated, viscid, and bitter, by stagnation in the gall-bladder; the cause of which is, in all probability, the absorption of its more watery parts by the lymphatic vessels."[b]

Many animals have no gall-bladder; *v. c.* the horse, goat, &c. All the carnivorous among the mammalia possess it, and all reptiles, most of which also are carnivorous; while those of the class mammalia that are destitute of it, are, with the exception of the porpoise and dolphin, vegetable feeders. Hence, Cuvier thinks that it is intended as a reservoir of bile where the animal is subject to long fasting from the uncertain supply of food. The gall-bladder is sometimes absent in the human subject. I have read of six instances of this.[c]

x "Vicq-d'Azyr, *Œuvres*, t. v. p. 343."

y "Casp. Fr. Wolff, *Act. Acad. Scient. Petropol.* 1779. P. ii."

z "Caldesi, *Osservaz. intorno alle Tartarughe.* Tab. ii. fig. 10.
But especially Wolff, lately commended, l. c. P. i. tab. vi.
Also Fr. Aug. Walter, l. c. tab. i."

a "Caldani, *Institut. Physiolog.* p. 364. sq. Patav. 1778. 8vo."

b "See Reverhorst, l. c. tab. ii. fig. 3.
Ruysch, l. c. tab. v. fig. 4.
Werner and Feller, l. c. tab. ii. fig. 5.
Mascagni, tab. xviii."

c *Phil. Trans.* 1749. The subject was a woman sixty years of age. Also l. c. 1813. *Transact. of the Coll. of Phys.* vol. vi. Mr. Cook's edition of Morgagni, *Gazette de France*, 1826; and *Journal Hebdomadaire*, referred to in the *London Medical Gazette*, 1829.

"Our attention must now be turned to the bile itself—a very important fluid, respecting the nature and use of which there has been more controversy for these forty years than about any other fluid.

"The cystic bile, being more perfect and better calculated for examination, will supply our observations.

"Bile taken from a fresh adult subject is rather viscid, of a brownish green colour[d], inodorous, and, if compared with that of brutes, scarcely bitter."

Berzelius[e] stated, that bile contains alkali and salts in the same proportion as the blood, and that no resin exists in it, but "a peculiar matter, of a bitter and afterwards somewhat sweet taste, which possesses characters in common with the fibrin, the colouring matter, and the albumen of the blood." This forms, with an excess of acid, a perfectly resinous precipitate. What was considered albumen in the bile, Berzelius regarded as the mucus of the gall-bladder.

Bile contained, according to him, of

Water - - - - - -	907·4
Biliary matter - - - -	80·0
Mucus of the gall-bladder dissolved in the bile -	3·0
Alkalies and salts common to all secreted fluids -	9·6
	1000·0[f]

Of the weight of alkalies and salts, more than one half was pure soda.

Tiedemann and Gmelin make the bile of the ox to consist of 91·51 water, with 7·30 proximate principles, and 1·19 salts. The biliary matter, or picromel, they find a compound of resin and a sweet crystallisable substance, which, together with another, termed by them biliary asparagin, renders the resin soluble in water. They discover also ozmazome[g], and a new acid — the cholic, also cholesterin, gliadine, casein, the oleic, acetic, phosphoric, sulphuric, and muriatic acids, and colouring matter. The

[d] "On the variety of colour in the bile, consult Bordenave, *Analyse de la Bile*, in the *Mém. Présentés*, &c. t. vii. p. 611. 617."

[e] *Animal Chemistry*, p. 65.

[f] *Med. Chirurg. Trans.* vol. iii. p. 241.

[g] A substance produced, like gelatin, by boiling, and obtained from muscle, serum, or even mushrooms; and, according to M. Raspail, it is a mere impure combination of albumen and acetic acid.

soda, they say, is not pure, but a bicarbonate, and mixed with a little potass.

M. Raspail remarks, that we may defy a chemist to either verify the analysis of Berzelius or Tiedemann and Gmelin, or not to increase the number of indeterminate substances which figure in them, and this the more minute he attempts to be. He considers, with M. Cadet, that bile is essentially a soap, with soda for its base, and mixed with sugar of milk; and that the other substances are all accessary. Thus, the bile of the pig is a soap with scarcely any albumen or picromel; that of birds contains a large quantity of albumen, and its picromel has no sugar; that of fish has no resin, and its picromel is very sweet, and slightly acrid; human bile has no picromel, and has the less resin the more fatty the liver. As to picromel, he regards it as a substance to be made at pleasure by mixing resin, sugar, and an alkali or acid.[h]

Fourcroy first explained the chemical operation of the bile in chylification.[i] According to Dr. Prout, during the precipitation of the chyle and the decompositio ·of the bile, a gaseous product is usually evolved, the mass bec ›mes neutral, and traces *of an albuminous principle* commence, strongest at a certain distance from the pylorus,—below the point at which the bile enters the intestine, and gradually fainter in each direction. On mixing bile with chyme out of the body, a distinct precipitation takes place, and the mixture becomes neutral; but the formation of an albuminous principle is doubtful, probably from the want of the pancreatic fluid.[k]

The bitter and bilious yellow matters pass off with the fæces, while the alkali (soda) of the bile probably combines with the acid, and contributes to the formation of the chyle. The sugar disappears. The loss of the alkali, which preserved the biliary yellow, bitter, resinous matters in solution, causes the separation of the latter; and Dr. Prout found their distinctive qualities the more evident, the further from the intestine they were examined.

It is no longer wonderful that in jaundice, so intense that no bile is seen in the fæces, and, according to Dr. Fordyce, even in artificial obstruction of the choledochus by ligature, nutrition continues, though, no doubt, less perfectly than in health. For

[h] l. c. p. 451. sqq.

[i] *Système des Connoissances Chimiques*, t. x. p. 49.

[k] Dr. Prout, Thomson's *Annals of Philosophy*, 1819. p. 273.

Tiedemann and Gmelin, after tying the biliary duct, which proved on dissection to have continued impervious [1], found the thoracic duct still containing an abundance of matter, yellowish, indeed, from the jaundice, but coagulating, and its coagulum becoming red, precisely like chyle; the small intestines had the soft flakes usually considered chyle, but thought mucus by them, and both large and small intestines contained nearly all the principles, except those of the bile, seen in sound animals; but the contents of the large intestines were exceedingly offensive. In the less satisfactory experiments of MM. Leuret and Lassaigne, the thoracic duct was still full of chyle.

Although the bile is seen, by experimenting upon the contents of the duodenum, to cause a precipitation (Tiedemann and Gmelin deny it, but Dr. Prout has almost constantly seen it), the chyle

In the year 1817, Dr. James Blundell tied the choledochus several times in the dog and rabbit, and has ever since mentioned the results in his physiological lectures. Generally the animal died of peritoneal inflammation, the bile forcing its way into the cavity among the viscera, when the ligature had produced ulceration; but when the animal did not die, the jaundice disappeared after a time, and the animal was nourished as before: the bile had found some outlet. On opening the animals, about a fortnight after the experiment, he discovered that fibrin had been effused round the tied portion of the duct, so as to re-establish the canal, and the ligatures had disappeared. Dr. Blundell's well-known accuracy renders all confirmation unnecessary, but I may mention, that Mr. Brodie and others have since made the same experiment with the same results.

Dr. Blundell has on record the cases of two infants, four or five months old in whom the hepatic ducts terminated blindly; so that no bile entered the intestines, and the stools were white, like spermaceti, and the skin jaundiced. But the infants grew rapidly, and throve tolerably notwithstanding. He therefore saw that nourishment could be accomplished without the mixture of bile and chyme. Of these cases, one was examined by Mr. Luke, of the London Hospital, the other by Mr. Gaunt, of Falcon Square.

Dr. Blundell has for many years been in the habit of displaying the precipitating agency of the bile upon the chyme, by varying the mode of admixture: 1. By working chyme and bile together, when the white chyle appears in the mass, like veins in marble: 2. By enclosing chyme in black silk, and wetting a part of the external surface of this printer's ball, as it may be called, with bile; when, on rendering it tense, the liquid portion of the chyme oozes through the texture, and renders it generally blacker, but whitens it conspicuously in those spots where it meets with bile: 3. By filtering the chyme repeatedly, and then dipping into the thin strained fluid a rod with a drop of bile at its extremity, white chyle appears at the point of contact.

He found the same results in the curious hybrid experiment, of employing the bile of a dog, and the chyme of a rabbit.

may thus be separated without it; but probably, Dr. Prout conceives, in less quantity and perfection.

The neutralising effect of the bile, he informs me, is evident on laying a piece of litmus paper through the pylorus, when the portion in the stomach becomes red, and that in the intestines is unaffected, or even shows alkaline agency.

The further down the intestinal contents are examined, the more do all traces of albuminous matters disappear, as well as of all the highly azotised[m] principles of the pancreatic juice, these being supposed to convert the unazotised principles of the vegetable food into albumen: in man and carnivorous brutes no traces of either are discoverable so low down as the cæcum.

Dr. Prout remarks, that "admitting that the decomposition of the salt of the blood is owing to the immediate agency of galvanism, we have in the principal digestive organs a kind of galvanic apparatus, of which the mucous membrane of the stomach, and perhaps that of the intestinal canal generally, may be considered as the acid or positive pole; while the hepatic system may, on the same view, be considered as the alkaline or negative pole."[n]

The hypothesis, that one great use of the liver was, like that of the lungs, to remove carbon from the system, with this difference, that the alteration of the capacity of the air caused a reception of caloric into the blood, in the case of the lungs, while the hepatic excretion takes place without introduction of caloric,— was, I recollect, a great favourite with me when a student, principally from the facts that a supply of venous blood—blood which has been used by the system—runs to both liver and lungs, and to no other organs; that the higher the temperature, the less carbon passed off by the lungs (less caloric being demanded by the body), and the more abundant, or more acrid, became the bile; so that bilious diseases are most prevalent in hot seasons and climates. The Heidelberg Professors have adduced many arguments to the same effect. In the fœtus, for whose temperature the mother's heat must be sufficient, the lungs perform no function, but the liver is of great size, and bile is secreted abundantly, so that the meconium accumulates considerably during the latter months of

[m] In examining the blood, we shall find that M. Raspail considers nitrogen to exist in animal and vegetable substances, combined with hydrogen as ammonia.

[n] *Bridgewater Treatise*, 496. sq.

pregnancy. We shall see, indeed, that at the very time the functions of the lungs suddenly begin at birth, the liver suddenly loses much of its supply of blood. Warm-blooded animals with large lungs, living in the air, have the liver proportionally smaller than those which live partly in water: in cold-blooded animals, and reptiles, which have lungs with such large cells as but slightly to decarbonise the blood; in fish, which get rid of carbon but slowly by the gills; and in the mollusca, which decarbonise still more slowly by gills or lungs,—the liver is proportionally large. More blood flows to the liver, accordingly as the lungs are less active organs. In the mammalia and birds it receives the blood of only the stomach, intestines, spleen, and pancreas; but in the cold-blooded, of many other parts; in the tortoise, of the hind legs, pelvis, tail, and vena azygos; in serpents, of the right renal, and all the intercostal veins; in fish, of the renal veins, the tail, and genitals. They assert, that in pneumonia and phthisis more bile is secreted, and in the *blue disease*, and other affections of the heart, that the liver is enlarged. The constituents of the bile contain a large quantity of carbon, which is chiefly in union with hydrogen, and under the form of resin or fatty matter, and resin is most abundant in the bile of herbivorous animals, whose food contains a very large proportion of carbon and hydrogen. In the lungs the carbon may be said to be burnt, whence animal heat; in the abdomen it passes off still combustible.

CHAP. VI.

OF THE FUNCTION OF THE SPLEEN.

"The *Spleen*[a] lies to the left of the liver, with which it has considerable vascular communications; by its oblong figure[b], it accommodates itself, as it were, to the contiguous viscera, but is liable to great varieties in point of form, number, &c.[c]

"Its colour is livid, its texture peculiar, soft, easily lacerated, and therefore surrounded by two membranes, the interior of which is proper to the spleen, and the exterior derived from the omentum.

"The situation and size of the spleen are no less various than its figure, and depend upon the degree of the stomach's repletion; for, when the stomach is empty and lax, the spleen is turgid; when the stomach is full, the spleen, being compressed, is emptied.

"It undergoes a continual, but gentle and equable, motion, dependent upon respiration, under the chief instrument of which—the diaphragm, it is immediately situated.

"Its texture was formerly supposed to be cellular, and compared to the corpora cavernosa of the penis."

Winslow says, "there are no venous ramifications in the ox and sheep. Having entered into the large end of the organ, the vein

[a] "Ch. Drelincourt, the younger, has carefully collected and concisely related whatever was known up to his time, respecting the spleen; *De lienosis*, at the end of his father's Opuscula. Boerhaave's edition, p. 710. sq.

Consult, also, Chr. Lud. Roloff, *De fabrica et functione lienis*. Frf. ad Viadr. 1750. 4to.

But among more recent writers, see L. J. P. Assolant, *Recherches sur la Rate*, Par. 10. 8vo.

C. F. Heussinger, *über den Bau und die Verrichtung der Milz*. Isen. 1817. 8vo.

And Chr. Hellw. Schmidt, *Commentatio* (which gained the royal prize) *de pathologia lienis*, &c. Gott. 1816. 4to."

[b] "Walter, tab. iii. G.
Mascagni, tab. xiv. P."

[c] "See Sandifort, *Natuur en genees-kundige Bibl.* vol. ii. p. 345. sq."

goes about an inch and a half; then, instead of being like other veins, it becomes perforated on all sides. The beginning of this canal has still a portion of the coats of the vein, but the form of the whole canal is gradually effaced, so that nothing remains but grooves in the cellular structure."[d]

"This opinion was proved," says Blumenbach, "to be erroneous by more careful examination of the human spleen [e], which consists entirely of blood-vessels, of enormous size in comparison with the bulk of the organ: they are, in fact, proportionably more considerable than in any other part of the body."

But Dr. Andral affirms, that "by repeated washing, the spleen is shown to consist of an infinite number of cells, which communicate on the one hand together, and on the other directly with the splenic veins. The latter, when the inner surface of the large subdivisions of the splenic veins are examined, appear to have a great number of perforations, through which a probe passes directly into the cells of the organ. The farther the subdivisions of the vein examined are from the trunk, the larger are these perforations; and still further on, the coats of the vein are not a continued surface, but are split into filaments, which do not differ from those forming the cells, and are continuous with them." "The cells are produced in the following manner: from the inner surface of the investing membrane of the spleen, a great number of filaments, fibrous like itself, are detached, some of which grow broad, and resemble flakes, and the latter chiefly seem intended to support the divisions of the artery. In interlacing each other, these filaments leave spaces, which are in fact the cells of the spleen, and they terminate by insertion into the walls of the veins, becoming continuous with the filaments into which the veins are ultimately reduced." These facts are readily ascertained in the spleen of the horse; but may also be verified in the human spleen.[f]

"The experiments of Wintringham demonstrate the great tenuity and strength of the coats of the splenic artery. It is divided into an infinite number of twigs, the terminations of which resemble pulpy penicilli and give rise to the splenic veins, which gradually unite into large, loose, and easily dilatable, trunks."

Andral says, that the splenic artery, almost as soon as it enters

[d] *Exposition Anatomique du Corps Humain*, t. iv. p. 136. sqq.

[e] "See Lobstein's Dissertation, *Nonnulla de Liene sistens*. Argent. 1773. 4to."

[f] *Précis d'Anatomie Pathologique*, t. ii. P. i. p. 416. sqq.

the spleen, rapidly diminishes, and subdivides into twigs, which cannot be traced, and appear to be distributed on the sides of the cells. The cellular structure of the spleen enables us to inflate it by the veins. Winslow, a century since, did this; and when inflated, it has a great resemblance to the lungs with large cells of certain reptiles.

The spleen of brutes has been removed, from the most remote period, without effect.[g]

At least twenty hypotheses respecting the use of the spleen have been advanced. In some, it has been regarded as a diverticulum to the blood.[h]

Above a century ago, Dr. Stukely[i], considering the spleen to consist entirely of complications and inosculations of arteries, veins and cells, nerves, and (as Malpighi asserted) "a muscular net-work of fibrillæ," supposed that it contracted and propelled its blood through the splenic vessels into those of the stomach, when this organ required a larger supply during digestion. He maintained, likewise, that it accelerated the motion of the blood in the mesenteric veins when the circulation in the vena portæ was sluggish, and that it answered various other purposes. The whole is an hypothesis now forgotten.

Some have thought it a diverticulum for the blood whenever this fluid is obstructed in any part of the body, as in the cold stage of fever, great efforts, &c. To prevent too much from being thrown upon organs which might be injured, the spleen, they contend, is formed to allow an accumulation in its substance. This is ingeniously defended by Dr. Rush.[k]

Dr. Haighton (Lectures at Guy's Hospital), and Mr. Saumarez (*New System of Physiology*), have explained its operations as a diverticulum in a very different manner. When the stomach is full, the compression experienced by the spleen impedes its circulation, and the blood makes its way the more copiously into the arteries of the stomach, liver, &c. But we have no proof that the repletion of the stomach compresses the spleen materially,

g "J. H. Schulze, *De splene canibus exciso*. Hal. 1735. 4to."

h "Vinc. Malacarne, *Memorie della Soc. Italiana*, t. viii. P. 1. p. 233.
A. Moreschi, *Del vero e primario uso della milza*. Milan, 1803. 8vo."

i *Of the Spleen, its description and history, uses and diseases, particularly the vapors, with their remedy. Being a lecture read at the Royal College of Physicians.* By Wm. Stukely, M.D. C.M.L. and S.R.S. London, 1722. folio.

k Cox's *Medical Museum*, Philad. 1807.

and thus can impede its circulation: a fact, indeed, which will be mentioned presently, renders this improbable. Besides, in ruminating animals, as Blumenbach observes, it lies next the first stomach or paunch, and if compressed, must be so before digestion begins; and in proportion as the fourth stomach fills, and digestion proceeds more actively, is the distension of the paunch diminished. It varies in situation in different animals, not being always attached to the stomach. The excitement, too, which the liver must experience when chyme irritates the extremity of the ductus choledochus, and still more the provision of a gall-bladder, must render such aid from the spleen superfluous to the liver. The infinite blood-vessels and excerning orifices of the stomach cannot, likewise, but furnish sufficient gastric juice, from the mere excitement which they must experience whenever the stomach contains food. No other glands habitually excited to occasional great activity have such a diverticulum.

A third view of its influence as a diverticulum is, that it serves for receiving a great part of the venous blood of the alimentary canal during chymification, and especially during chylification. When this process is going on, there must be a great increase of blood flowing to the alimentary canal; the vena portæ, through which it all flows, can dilate to only a certain extent, and, in order to prevent such a congestion in the mesenteric veins as would retard the circulation in the organs, the spleen allows an accumulation in itself. Leuret and Lassaigne found the spleen of a dog weigh a pound and a half in two hours after the application of a ligature to the vena portæ, while it ordinarily weighs but two ounces; and observe that it has a vermilion tint when an animal is fasting, but grows turgid and of a dark purple when the chyme has passed the pylorus.

If the opinion of Erasistratus, that the spleen is useless, was a little atheistical, the notion of Paley was not much better, — that the viscera contained, and the abdomen containing, are so clumsily adapted to each other, that a pad is necessary to make them fit, just as hatters put stuffing under the leather of a hat which is made too big for the head, — "It is possible, in my opinion, that the spleen may be merely a stuffing, a soft cushion to fill up a vacuum or hollow, which, unless occupied, would leave the package loose and unsteady."[1] When I consider the stupendous

[1] *Natural Theology*, c. xi.

power and design displayed throughout nature, I instantly revolt at such an explanation as Paley's, to say nothing of its anatomical absurdity.

Sir Everard Home once fancied that the spleen is intended to receive "a great portion of our *drink* from the *cardiac* end of the stomach, so that these may pass through a short cut, hitherto unknown, from the stomach to the spleen, and thus into the mass of blood."[m] His friends having, among other experiments, passed a ligature around the pyloric extremity of the stomach of a dog, injected into this receptacle a solution of rhubarb; and, on killing the animal, some few hours afterwards, none of the absorbents of the stomach were found distended, nor could any trace of rhubarb be detected in the liver, but evident traces existed in the spleen and in the urine. When fluids had been drunk, the spleen was turgid, and exhibited cells full of a colourless liquid that were at other times collapsed and almost imperceptible,—a circumstance rendering it unlikely, I may remark in reference to Dr. Haighton's hypothesis, that the spleen is diminished in bulk by the distension of the stomach; for, first, compression, sufficient to prevent the artery from sending into it the usual quantity of blood, would prevent the entrance of fluids by any other vessels; and, secondly, we learn that the spleen is actually distended by the fluid portion of the contents of the stomach.

During the distension of the spleen, when the pylorus was not tied, the rhubarb appeared more strongly in the blood of the splenic than in that of other veins. If coloured solids without fluids were introduced into the stomach, the cells of the spleen were not distended, nor did this organ or its veins give more signs of the colouring matter than others.

Unfortunately, the size of the spleen is considerable, in those warm-blooded animals which never drink; as well as in bisulcous animals, whose spleen adheres to the paunch, receiving the crude food only, but never the drink, which is prevented from entering it by the well-known mechanism of a semicanal running from the œsophagus to the omasum.

From later experiments, published in 1811, the writer completely changed his opinion. It seems that traces of rhubarb were discoverable in the bile as well as in the spleen: and that it tinged

[m] *Phil. Trans.* 1808.

the urine if the spleen had been removed before the experiment: so that the burner of John Hunter's manuscripts abandoned what he had before advanced as a discovery, and regarded the spleen rather as a secreting organ, and its large and numerous lymphatic vessels, running to the thoracic duct, as supplying the place of an excretory canal.

CHAP. VII.

THE FUNCTION OF THE OMENTUM.

"The omentum gastro-colicum or magnum[a] (to distinguish it from the parvum or hepato-gastricum[b]) is a peculiar process of peritonæum, arising immediately from the external coat of the stomach.

"Although there are innumerable continuations of the peritonæum in the abdomen[c], and every abdominal viscus is so covered by it that on opening the abdomen nothing is found destitute of that membrane, nevertheless, it is afforded in different ways, which may be reduced to classes.

"Over some the peritonæum is merely extended as a smooth membrane, or it affords to them only a partial covering, as is the case with respect to the kidneys, rectum, urinary bladder, and, in some measure, with respect to the pancreas and gall-bladder.

"To some which project into the cavity of the abdomen, although adhering to its parietes, it affords a covering for the greater part of their surface; *v. c.* to the liver, spleen, stomach, uterus, and the testes of the very young fœtus.

"The intestinal tube, with the exception of the rectum, projects so much into the cavity of the abdomen, that it is, as it were, suspended in loose processes of the peritonæum, called mesentery and mesocolon: the broad ligaments of the uterus are similar to these.

"The longest and most remarkable process of peritonæum is the *omentum*—a large, empty, delicate sac, hanging from the

[a] "Eustachius, tab. ix.

Haller, *Icones anat.* fasc. i. tab. iv. K. M., and the Appendix Colica, which he himself investigated at Göttingen in 1740. ib. R.

Rob. Steph. Henry, *Descript. omenti c. icone nova.* Hafn. 1748. 4to."

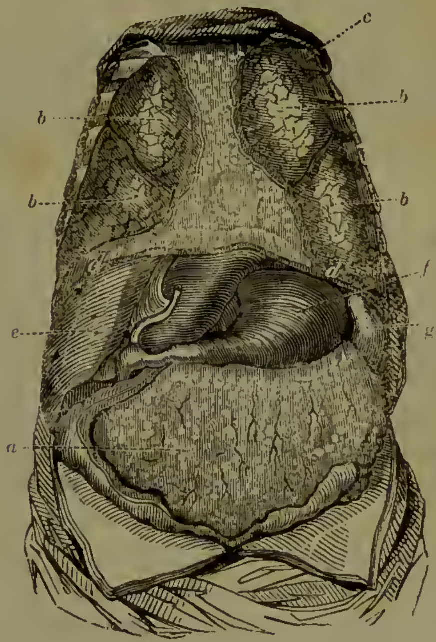
[b] "Eustachius, tab. x. fig. 1. G. H.

Haller, l. c. Q."

[c] "C. J. M. Langenbeck, *Commentarius de structura peritonæi*, &c. Gött. 1817. 4to. with copper-plates."

large curvature of the stomach, extending over the greater part of the small intestines, applying itself closely to their convolutions, and, in some measure, insinuating itself into their interstices.

"Besides the blood-vessels seen upon the omentum, it is marked by fatty striæ or bands, which are every where reticulated (whence the German name (Netzhaut) of this membrane), and in corpulent persons increase occasionally to a large and even dangerous size; and, by their means, the whole omentum is lubricated with a halitus, which one might almost call adipose.



a, omentum.
b, lungs.
c, mediastinum.
d, diaphragm.
e, liver.
f, stomach.
g, spleen.

"On the latter circumstance depends the use commonly ascribed to the omentum,—of lubricating the intestines and assisting their continual movements: this also appears the use of those analogous small bursæ which are found[d] in such numbers about the rectum[e] and colon.[f]

"The omentum also prevents the adhesion of the intestines to the peritonæum, and the consequent impediment to the functions of the primæ viæ.

[d] "I have lately seen similar appendices on the peritonæal covering of an uterus unimpregnated, but which had formerly been pregnant."

[e] "Walter, tab. ii. *m. m. m.*"

[f] "Bidloo, *Anatomia hum. corporis*, tab. xxxix. fig. 6. C.C.C. D.D.D."

"There is another two-fold office attributed with great probability to the omentum [g], *viz.* that of facilitating the dilation of the viscera to which it is contiguous, and of acting as a diverticulum to their blood during their state of vacuity.

"If we reflect on the singular structure of the omentum parvum or hepato-gastricum especially, we may be inclined to believe that there is another, and perhaps, principal office attached to it, unknown at present, and discoverable by comparative anatomy."

[g] "v. Chaussier. *Mémoires de l'Acad. de Dijon.* 1784. Semestr. iii. p. 95."

CHAP. VIII.

THE FUNCTION OF THE INTESTINES.

"The intestinal tube, over which the omentum is extended, and which receives the chyme to elaborate it further and separate the chyle from the fæces, is divided into two principal portions—the small and large intestines, of whose functions we shall speak separately.

"The small[a] intestines are again divided into three: the duodenum, jejunum, and ileum.

"The first is named from its usual length.

"The second from generally appearing collapsed and empty.

"The third from its convolutions: it is the longest of the three, fuller, and, as it were, inflated, and sometimes resembling the large intestines by the appearance of bullæ.

"The coats of the small intestines correspond with those of the stomach.

"The *external* is derived from the mesentery.

"The *muscular* consists of two orders of fibres: the one longitudinal, interrupted, external, and found especially about the part opposite the mesentery; the other, annular and falciform, possessing the power of narrowing the canal, while the former shortens it. Upon both depends the very great and permanent irritability of the intestines, formerly mentioned.

"The *nervous* coat is condensed cellular membrane, easily reduced by handling, or more particularly by inflation, into a spumous tela[b]; in it the intestinal blood-vessels, which arise from the mesenteric[c], are distributed in a beautifully arborescent

[a] "Chr. Bernh. Albinus, *Specimen anat. exhibens novam tenuium hominis intestinor. descriptionem.* LB. 1724. 8vo."

[b] "B. S. Albinus, *Annotat. Academ.* L. ii. tab. iv. fig. 1, 2."

"Eustachius, tab. xxvii. fig. 2. 4."

form [d]; the intestines, no less than the stomach, are indebted to it for their tenacity and strength.

" The interior, lined by its delicate epithelium, and deserving the name of *villous* in the small intestines more than in any other part of the canal, forms, in conjunction with the inner surface of the former coat, here and there, undulated ridges and rugous plicæ, which, in dried and inflated intestines, resemble the blade of a scythe, and are termed the valvulæ conniventes or Kerkringhianæ.[e]

" The *villi*, which are innumerable[f] upon the inner surface of the intestines, and whose beautiful and minute vascular structure was first carefully investigated, though described with exaggeration, by Lieberkühn[g], may be, perhaps, compared, while destitute of chyle, to little loose pendulous bags, internally soft and spungy; but, when distended with chyle, they have the appearance of a morel.

" The base of these villi is surrounded by innumerable *glandular follicles*, adhering chiefly to the nervous coat, and opening into the intestinal canal by a very small orifice, through which they discharge the mucus that lines the whole track of the intestines.

" These are distinguished into three orders. The Brunnerian, largest, solitary, found in most abundance in that part of the duodenum which is contiguous to the pylorus.[h] The Peyerian, smaller, aggregated, found chiefly at the termination of the small intestines,—about the valve of the colon.[i] Lastly, the Lieber-

[d] " B. S. Albinus, *Dissert. de arteriis et venis intestin. hominis*, with coloured plates. LB. 1736. 4to.

Also his *Annotat. Acad.* L. iii. tab. i. ii."

[e] " Kerkring, *Spicilegium anatomicum*, tab. xiv. fig. 1, 2."

[f] " He estimated their number, in the small intestines of an adult, to be about 500,000."

[g] " *De fabrica et actione villorum intestinor. tenuium hominis.* LB. 1745. 4to.

J. Bleuland, *Descriptio vasculorum in intestinorum tenuium tunicis.* Ultraj. 1797. 4to.

R. A. Hedwig, *Disquisitio ampullarum* Lieburkühnii. Lips. 1797. 4to.

C. A. Rudolphi, *Anatomisch-physiologische Abhandlungen.* Berlin. 1802. 8vo. p. 39."

[h] " J. Conr. a Brunn, *Glandulæ duodeni s. pancreas secundarium.* Francof. 1715. 4to. fig. 1."

[i] " J. Conr. Peyer, *De Glandulis intestinorum.* Scafhus. 1677. 8vo. especially fig. 3."

kühnian, the smallest, said to be distributed in the proportion of about eight to each villus.[k] The two former orders are so inconstant, that I am inclined to consider the view given of them in the plates alluded to, as morbid[l]; for I have more than once been unable to discover the slightest trace of fungous papillæ with a single pore, in the small intestines of healthy adults; while, on the contrary, in *aphthous* subjects, I have found nearly the whole intestinal tube beset with them in infinite numbers, both solitary and aggregated.[m]

"As the gastric juice is poured into the stomach, so an *enteric* or *intestinal fluid* is poured into the small intestines, demonstrated, among other ways, by the common experiment, first, we believe, instituted by Pechlin[n]," of including a portion of intestine between two ligatures, so that the fluid secreted into it may be collected. "An accurate investigation of it is a physiological desideratum. We can say nothing respecting its quantity, but Haller's estimate — eight pounds in the twenty-four hours — is certainly excessive.

"The intestines agree with the stomach in this particular, that they have a similar, and, indeed, a more unquestionable, or, at least, a more lively, *peristaltic action*[o], which occurs principally when the chymous pulp enters them. This it agitates by an undulatory constriction of different parts of the canal, and propels from the duodenum towards the large intestines. Although the existence of an antiperistaltic motion, causing a retrograde course to their contents, cannot be disproved, it is in health much weaker, and less common and important, than the former.

"By these moving powers, and by these solvents which are afforded by means of secretion, the chyme undergoes remarkable changes."[p]

[k] "Lieberkühn, l. c. p. 17. tab. iii."

[l] "The eminent Rudolphi thinks differently, l. c. p. 212."

[m] "These intestinal *aphthæ* exactly resemble those tubercles which Sheldon, in a work which we shall presently quote, exhibits (Tab. 1.) as small ampullæ full of chyle."

[n] "*De purgantium medicamentor. facultat.* p. 509. — tab. iv."

[o] "Benj. Schwartz, *De vomitu et motu intestinorum.* LB. 1745. 4to. J. Foelix, *De motu peristaltico intestinorum.* Trevir. 1750. 4to."

[p] "Consult the excellent observations and experiments of A. E. Ferd. Emmert, *Archiv für die Physiologie*, t. viii. p. 145."

Albumen and albuminous substances, which are the source of the chyle and so abundant in the duodenum and jejunum, gradually disappear, so that a great part of the chyle is generally formed and absorbed before the digested mass reaches the ileum.[q] The contents become of a brownish yellow colour, and of a disgusting odour.

" After becoming more and more inspissated in their long course through the ileum, they have to overcome the valve of the colon and pass into the large intestines. To facilitate this, the extremity of the ileum is lubricated very abundantly by mucus.

" The *valve of the colon*[r], or, as it may deservedly be termed after its discoverer, the valve of Fallopius[s], is a short process or continuation of the portion of the ileum that penetrates into and is surrounded by the cavity of the large intestine. Its external lips, while a neighbouring fold of the large intestine at the same time projects considerably, are composed[t], not like other similar folds, merely of the interior and nervous coats, but

[q] Dr. Prout, Thomson's *Annals of Philosophy*. 1819.

[r] " Haller, *De valvula coli*. Gotting. 1742. 4to., reprinted in his *Oper. minor*. t. i. p. 580. sq.

T. Mich. Röderer, *De valvula coli*. Argent. 1768. 4to."

[s] " The various opinions respecting the discoverer of this remarkable valve are well known. Haller's *Elementa*, t. vii. P. I. p. 142., may be consulted on this point.

In the mean time I am certain that, long before the period at which its discovery is in general dated, it was accurately known to that immortal anatomist Gabr. Fallopius. In the library of our university there is a manuscript of Fallopius, containing, among other things, his *anatomy of the monkey*, in which is an account of the structure and use of the valve of the colon, delivered in a public demonstration at Padua, Feb. 2. 1553, in the following words : ' *The use of the cæcum in the monkey is to prevent the regurgitation of the food during progression on all fours. This is proved by the circumstance of water or air, thrown into the rectum, reaching the cæcum, but not passing beyond the large intestines. But, if impelled from above, it passes into them. The reason is this, — at the insertion of the ileum are two folds, which are compressed by inflation and repletion, as occurs in the heart, and prevent retrogression; wherefore, in man, clysters cannot pass and be rejected through the mouth, unless in a weak and diseased state of the intestines.*' "

[t] " A view of a recent and entire valve is exhibited by B. S. Albinus in his *Annotat. Acad.* L. iii. tab. v. fig. 1.

And overcharged by inflation and drying, in Santorini's Posthumous Tables, xiv. fig. 1, 2."

of fibres from the muscular coat also. Hence it performs the double office of preventing the passage of too great a quantity of fæces into the large intestines, and regurgitation into the small."

a, ileum.
b, cæcum.
c, colon.
d, valve.

It probably always prevents regurgitation even of air, while entire: and the contents of the ileum are so often seen fæcal in dissection, that stercoraceous vomiting is no argument that the valve occasionally allows retrogression of the intestinal contents.[u]

"The large intestines, divided like the small into three parts, commence by the *cæcum* (which has a *vermiform process* whose use in man is unknown [x]), and afford a very ample receptacle, in which the fæces may be collected and retained, till an opportunity for discharging them arrives.

"They exceed the small intestines in thickness and strength, as well as in capacity. The muscular coat has this peculiarity—that its longitudinal fibres, excepting at the extremity of the rectum, are collected into three bands, called ligaments of the colon [y]; and the intestines themselves are divided into a kind of bulbous segments. The inner coat is not so beautifully flocculent as that of the small intestines, but more similar to that of the stomach.

[u] *New Views of the Process of Defecation, &c.* By James O'Beirne, M.D. Dublin, 1833, p. 16. sq.

[x] "Lieberkühn, *De valvula coli et usu processus vermicularis.* LB. 1739. 4to. Joach. Vosse, *De intestino cæco ejusque appendice vermiformi.* Gotting. 1749. 4to."

[y] "Eustachius, tab. x. fig. 2. 4, 5."

" Their peristaltic motion is much fainter than that of the small intestines. On the other hand, they experience to a greater degree the pressure of the abdominal parietes, to which the whole length of the *colon* is contiguous."

On arriving in the large intestines, the mass of contents undergoes fresh changes, at present unexplained, and is converted into true excrement or fæces.[z] Here it is that a peculiar *succus entericus* must be poured forth, for the secretion into the small is probably nothing more than mucus and a simple watery fluid. Tiedemann and Gmelin support, in some measure, the old idea of the cæcum being a subsidiary stomach, from its contents being acid although acidity had disappeared higher up in the canal, and more acid as the aliment is less digestible; and from albumen often reappearing suddenly in this part of the canal. Dr. Prout found the fluids of the large intestines coagulate lymph even as low as the rectum.

The excrementitious mass, consisting of the indigestible part of the food, the resinous colouring and fatty matters of the bile, with intestinal mucus, loses its fluids gradually as it descends, and in the lower part of the intestines becomes particularly dry.[a]

The fæces appear to accumulate in the sigmoid flexure of the colon, the lower and greater part of which, when empty, falls into the pelvis, hanging doubled over. As the fæces accumulate, this turns upon the rectum, until at length, like the stomach, its greater arch is placed forwards and upwards, and its contents are brought somewhat perpendicular to the upper end of the rectum. When the accumulation amounts to a certain degree, that intestine and the abdominal muscles and diaphragm are excited to simultaneous action, the whole contents pass down into and force open the rectum, which, in its turn, is presently excited in the same way, and the same powers[b] " overcome the resistance of the os coccygis and of both sphincters, the inner of which is a remarkable bundle of circular fibres, the outer, a truly cutaneous muscle. After the excretion, the effort of the abdomen having ceased, the levator ani chiefly retracts the intestine, which is again closed by its sphincter."[c]

[z] See Abernethy, *Surgical Observations*, Part II. p. 34.

[a] The excrements of brutes have been analysed, but not to an extent capable of affording general views.

[b] Dr. O'Beirne, l. c.

[c] " All these parts may be seen as they exist in each sex, in Santorini's Posth. Tables, xvi. and xvii."

It is generally believed that the fæces collect in the rectum, till their quantity

"The discharge is facilitated by the absence of transverse rugæ, and especially by the great quantity of mucus at the extremity of the bowels."

The alimentary canal always contains gaseous substances, which, being chiefly disengaged from its contents, must vary at different parts of the canal. These serve the important purpose of gently causing the canal to open progressively for the advance of soft or solid contents.

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stimulates it to discharge them. Dr. O'Beirne, in his very original work, argues successfully against this, 1st, from the inconvenience to the bladder and the constant irritation of the sphincter ani, were accumulation to occur there, so that the rectum is ill circumstanced for accumulation, whereas the cæcum and colon really appear constructed for receptacles. 2d, The sigmoid flexure is a great depôt for fæcal matter, and therefore a free passage at all times into the rectum is unlikely. 3d, Great force is usually required to force injections up the rectum, as if it were naturally contracted and close. 4th, The finger or an instrument introduced into the rectum is rarely soiled by fæces. 5th, Adhesions within the rectum have often been found, but seldom or never in the other intestines, and they must require an empty condition of the cavity for the necessary contact of the sides. 6th, After division or destruction of the lower sphincter of the anus, the fæces are generally retained as usual. 7th, He has examined the rectum with a long tube in many healthy persons several times a day, and never found fæces in it. Besides the muscular fibres possessed by the rectum in common with the colon, it has strong fleshy fibres, circular and longitudinal, and it alone receives nerves of sense and motion from the spinal marrow.

Dr. O'Beirne considers, also, that an accumulation naturally occurs in the cæcum as well as in the colon, from the great acuteness of the angle at which the ileum enters the cæcum; the greater capacity of the cæcum than of either the ileum or colon; the course of the colon against gravity; the necessity of the cæcum being filled before it can be excited to or supported in an expulsive effort; and the distention of the colon all the way from the cæcum to the sigmoid flexure by gas, which prevents the ascent of the fæces from the cæcum till it escapes from the lower bowel. He conceives that the whole contents are transferred at once: and as, at the time of defecation, there is usually one mass in the sigmoid flexure and one in the cæcum, that the amount of the two is the evacuation; and as two distinct acts of expulsion are always required before the bowels in health are sufficiently freed, that the capacity of the rectum may be received as the measure of that of the cæcum. When he has had every reason to believe that no fæces were in the sigmoid flexure, from a hollow bougie passed into it remaining unsoiled, flatus escaped; and, on passing the instrument again in five minutes, its upper extremity has been coated with fæces, and a solid evacuation soon occurred.

I think that the sympathy between the stomach and the large intestines, when these are charged, deserves notice. When the intestinal contents have accumulated, the repletion of the stomach by even a moderate meal excites the lower portion of the canal to discharge its contents, so that a meal at such a time causes a desire for relief, and the more as the meal is greater.

The gas of the stomach contains, besides azote and carbonic acid gas, oxygen, and very little hydrogen; while that of the small intestines contains, besides the two former gases, no oxygen, and abundance of hydrogen: that of the large intestines has less hydrogen and carbonic acid, and likewise no oxygen. Little or no gas is found in the stomach during chymification.

The following are the results of MM. Magendie's and Chevreuil's analysis of the gases of the alimentary canal:

In the stomach of a man just executed,—

Oxygen - - -	11·00
Carbonic acid - - -	14·00
Pure hydrogen - -	3·55
Azote - - -	71·45
	100·00

In the small intestines of a subject, four-and-twenty years of age, who had eaten, two hours before execution, bread and Gruyère cheese, and drunk eau rougie,—

Oxygen - - -	0·00
Carbonic acid - -	24·39
Pure hydrogen - -	55·53
Azote - - -	20·08
	100.00

——— twenty-three years of age, who had eaten the same food, and was executed with the former,—

Oxygen - - -	0·00
Carbonic acid - -	40·00
Pure hydrogen - -	51·15
Azote - - -	8·85
	100·00

——— twenty-eight years of age, who, four hours before execution, had eaten beef, bread, lentils, and drunk red wine,—

Oxygen - - -	0·00
Carbonic acid - - -	25·00
Pure hydrogen - -	8·40
Azote - - -	66·60
	100·00

In the large intestines of these three criminals, were found,—

Oxygen - - -	0·00
Carbonic acid - -	43·50
Carburetted hydrogen and some traces of sulphuretted hydrogen	5·47
Azote - - -	51·03
	100·00

Oxygen - - -	0·00
Carbonic acid - -	70·00
Hydrogen and pure carburetted hydrogen - -	11·06
Azote - - -	18·04
	100·00

The gas of the cæcum and rectum of the third was examined separately.

Cæcum,—

Oxygen - - -	0·00
Carbonic acid - -	12·50
Pure hydrogen - -	7·50
Carburetted hydrogen -	12·50
Azote - - -	67·50
	100·00

Rectum,—

Oxygen - - -	0·00
Carbonic acid - -	42·86
Carburetted hydrogen -	11·18
Azote - - -	45·96
	100·00

Some traces of sulphuretted hydrogen appeared upon the mercury before the last analysis was commenced.

Berzelius finds human excrement to consist of

Water - - -	73·3
Remains of vegetable and animal matter - - -	7·0
Bile - - -	0·9
Albumen - - -	0·9

Peculiar extractive matter -	2·7
Matter composed of altered bile, resin, animal matter, &c. -	14·0
Salts - - -	1·2
	100·0 [d]

Besides the gases disengaged from the contents of the canal, at least the stomach contains a portion of air that has been swallowed with the food, and many persons can easily *swallow air by itself.* Air is perhaps generated occasionally in the womb, and is undoubtedly generated by serous membranes. Emphysema has occurred without any wound of the lungs. I believe, with John Hunter [e], that the alimentary canal also often secretes gaseous fluids. For mental emotion will suddenly cause extreme discharges of air from the stomach, and the intestines to swell with wind. Want of food fills the stomach with wind. In many diseases the same will occur, although no fermentation or unusual change is discernible in the contents of the canal.

Air in the serous membranes, or in the cellular, even when introduced, is known to be absorbed. [f]

Every one knows that the intestines are usually relieved once in twenty-four hours, but that some little variety occurs in this respect. In cases of extreme abstinence, they of course discharge their contents very rarely, as I mentioned formerly. Heberden, however, mentions a person who naturally had a motion once a month only, and another who had twelve motions every day during thirty years, and then seven every day for seven years, and rather grew fat than otherwise. [g] Habit has the greatest influence upon defecation.

Pouteau's young lady, mentioned at page 55., had no stool, he says, for upwards of eight years, although during the last year she ate abundantly of fruit, and drank coffee, milk, and tea, and broth with yolks of eggs: but she had copious greasy sweats.

[d] *Traité de Chimie,* tom. vii. Traduit par M. Esslinger.

[e] *Observations on certain Parts of the Animal Economy.*

[f] See Dr. Baillie in *Transact. of Society for Improvement of Med. and Surg. Knowledge,* vol. i.

[g] *Commentarii,* p. 14.

CHAP. IX.

THE FUNCTION OF THE ABSORBENT VESSELS.[a]

"The course of the chyle[b] from the intestines to the blood is through a part of the absorbent system."

"This is divided into four parts—*lacteal* and *lymphatic vessels*, *conglobate glands*," (or *ganglia*, as they are now often termed,) "and the *thoracic duct*. Each of these will be now considered.

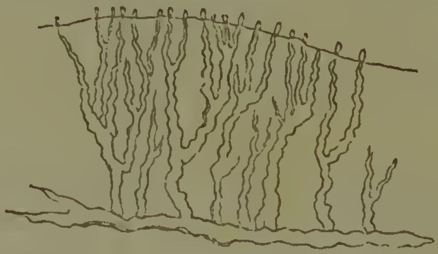
"The *lacteals* originate among the villi of the internal coat of the intestines;" but most writers have been unable to detect their origin. Lieberkühn and Cruikshank, however, appear to have been successful. The former says, that each villus is a lacteal with valves, swelling into a bulb or ampulla at its termination, on the summit of which is an orifice. The latter opened a woman who had died suddenly of convulsions after taking a hearty supper in perfect health. "Many of the villi," he says, "were so full of chyle that I saw nothing of the ramifications of the arteries and veins; the whole appeared as one white vesicle, without any red lines, pores, or orifices whatever. Others of the villi contained chyle, but in a small proportion; and the ramifications of the veins were numerous, and prevailed by their redness over the whiteness of the villi. In some hundred villi I saw the trunk of a lacteal forming a beginning by radiated branches. The orifices of these radii were very distinct on the surface of the villus, as well as the radii themselves seen through the external surface, passing into the trunk of the lacteal: they were full of a white fluid. There was but one of these trunks on each villus. The orifices in the villi of the jejunum, as Dr. Hunter himself said, (when I asked him, as he viewed them in the microscope, how many he

[a] "A very copious list of writers upon the absorbents will be found in Sömmerring's work, *De morbis vasorum absorbentium corporis humani*. Francof. 1795. 8vo."

[b] "Ant. Müller, *Experimenta circa chylum*. Heidelb. 1819. 8vo."

thought there might be,) were about fifteen or twenty in each villus; and in some, I saw them still more numerous."[c]

M. Cruveilhier opened a man who had died with scrofulous disease of the mesenteric ganglia and coats of the lacteals and intestines, the latter being ulcerated. The lacteals were distended with both a cheeselike substance and another like cream. This circumstance displayed them fully. From the floating margin of the valvulæ conniventes, innumerable lacteals ran straight and parallel to each other; their numbers were such, that the cellular membrane between the layers of the mucous membrane almost seemed to consist of them. They, few or more, united, and terminated, sometimes at nearly right angles, in long vessels, which ran pretty much in the direction of the valvulæ conniventes at their fixed margin, and each of these passed a considerable way under the peritoneal coat without connection, not forming a network, as is usually represented.



M. Cruveilhier states, that some papillæ of the intestines have black summits, and in these he could never detect a lacteal: that others have yellow summits, and in the centre of such he has found a lacteal, thread-like, conical, or bulbous, according to its degree of distention. The papillæ, each with its lacteal, project and float about in water like the fibres of roots. He has never detected the orifices.[d]

" The trunks just mentioned run some inches along the surface of the intestines, under the external coat, sometimes meandering in an angular course, before they reach the mesentery."

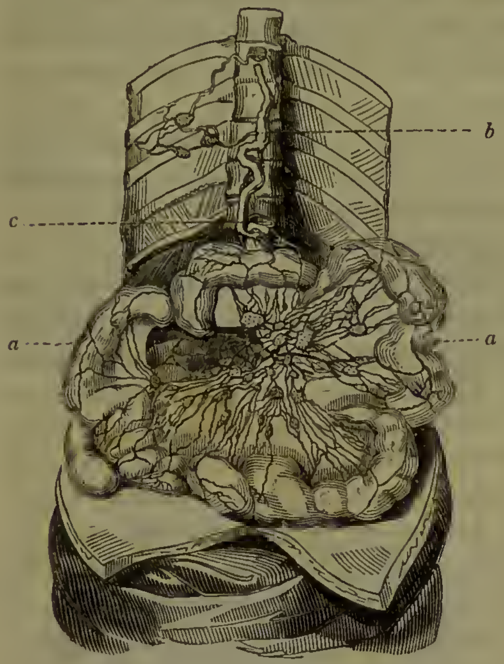
The lacteals are abundantly supplied with valves.

" In their course through the mesentery they run into the mesenteric *glands*," (or *ganglia*,) " of which there are two series.

[c] *Anatomy of the Absorbing Vessels*, p. 59.

[d] *Anatomie Pathologique du Corps Humain*. Deuxième livraison, p. 1. sqq. Paris, 1830.

The one nearer the intestines, dispersed, small, and resembling beans in shape; the other, nearer the receptaculum chyli, large and aggregated."



a, Small intestine, so pushed aside as to display the lacteal vessels running from them to their glands or ganglia in the mesentery.
b, The thoracic duct, ascending in front of the spine.
c, The aorta cut short.

If a gland is well injected, the numerous ramifications of the absorbents prevent cells from appearing, and it seems only a closely compacted collection of lacteals; but, if injected less minutely, cells are very evident, and distinct from the convolutions and ramifications of vessels.[e] "If an absorbent gland of a horse is filled with quicksilver and dried, and then carefully slit open, the cells will be seen of a large size, and bristles may with ease be passed through the openings by which they communicate." It is imagined that the vasa inferentia (or vessels running into a gland) pour their contents into these cells, and that the efferentia (or the vessels running from a gland) afterwards absorb it from them. The inferentia are fewer, in general, than the efferentia of the same gland.

"It has been enquired whether lacteals exist also in the large intestines, and their existence has been advocated, from the effects of particular injections, nutrient, inebriating, &c., and also from the circumstance that the fæces, if retained for any length

[e] Wilson, *Lectures on the Blood, &c.* p. 203. Mr. Abernethy described them in the whale, as well as in the horse. *Phil. Trans.* 1796.

of time, become hard and dry. Although these arguments do not demonstrate the absorption of genuine chyle below the valve of Fallopius, nevertheless it is rendered probable by the visible existence of an abundance of lymphatics in the large intestines [f], having the same structure and function with the lacteals; for these absorb lymph from the intestines [g] during the absence of chyle.

"But the very different structure of the internal coat of the large intestines from that of the villous coat of the small, strongly argues that they are not naturally intended to absorb chyle."

Some contend that the lacteals take up nothing but chyle.

Dr. Magendie [h] asserts that neither he nor Hallé has ever seen the chyle in these vessels tinged by coloured ingesta, and that neither he nor the veterinary surgeon Flandrin ever found any thing but chyle enter the lacteals. Lister's experiment [i] of making puppies swallow indigo, and finding the contents of the lacteals blue, has succeeded with Musgrave, Haller, Blumenbach [k], John Hunter, Fordyce [l], and numerous others; and J. Hunter, in the presence of several persons, poured milk into the intestines of a dog, and they all observed it quickly to fill the lacteals. Among other insignificant objections, Dr. Magendie urges that J. Hunter should have first noticed whether the vessels contained chyle, whereas it is expressly mentioned that, before the milk was poured into the intestine, the lacteals were seen distended by a nearly colourless and pellucid fluid.[m]

Tiedemann and Gmelin, however, have made an abundance of these experiments with the same result as Magendie, though in some few instances the substance introduced into the canal was discovered in the chyle. Fiscinus and Seilar [n] say exactly the same as Tiedemann and Gmelin. They occasionally could detect metallic salts, and even turmeric and madder, in the chyle. Franchini [o] says, that, when the contents of the lacteals look blue,

[f] "Mascagni, tab. xvi."

[g] "See Nuck, *De inventis novis ep. Anatomica*, p. 146. sq."

[h] *Précis Elémentaire*, &c. t. ii. p. 178. sq.

[i] *Phil. Trans.* No. 143. compared with No. 275.

[k] *Instit. Physiol.* § 422.

[l] *On the Digestion of the Food*, p. 122.

[m] *Medical Commentaries.*

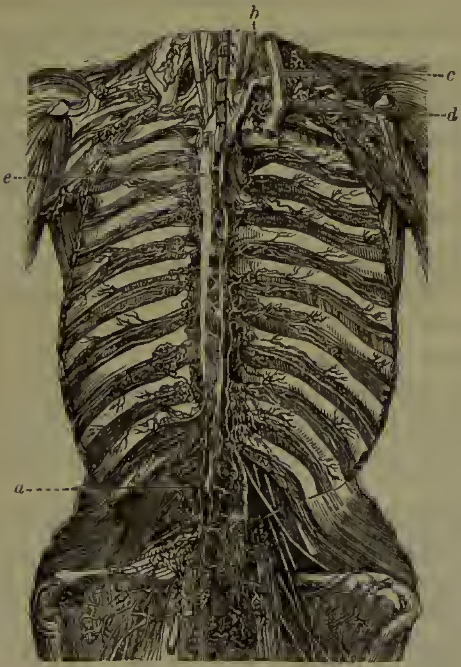
[n] Dresden. Republished in the *Journ. Complémentaire du Dictionnaire des Sc. Med.*

[o] Bologna. 1823.

they prove limpid on being let out; and that when red substances have been swallowed, and they look red, this arises from the abstinence, which always causes the fluid of both lacteals and lymphatics to become red.

"The ultimate trunks of the lacteals, arising, like the lymphatics, from the combination of a great number of small twigs [p], unite into the *receptaculum* or *cisterna chyli*, — the appellation by which the lower and larger part of the *thoracic* or PECQUETIAN *duct* is distinguished.

"This duct is [q] a membranous canal," consisting of an external fibrous, and a smooth inner serous coat, "slender, strong, more or less tortuous, subject to great varieties in its course and division [r], and possessing here and there valves. At about the lowest cervical vertebra, after passing the subclavian vein, it turns back again [s], and is inserted into this, being furnished with a peculiar valve at the point of insertion.



a, receptaculum chyli.
b, upper end of the thoracic duct, which bends behind
c, the internal jugular vein, and terminates in
d, the angle of the jugular and subclavian veins.
e, vena azygos.

p "Sheldon, l. c. tab. v."

q "See Haller, *Observationes de ductu thoracico in theatro Gottingensi factæ*. Gotting. 1741. 4to.

B. S. Albinus, *Tabula vasis chyliferi*. LB. 1757. large folio.

Mascagni, tab. xix."

r "See *v. c.* J. C. Bohl, *Viæ lacteæ. c. h. historia naturalis*. Regiom. 1741. 4to. Sömmerring, *Commentat. Soc. Scient. Gottingens.* t. xiii. p. 111."

s "*v.* Haller, *Opera Minora*, vol. i. tab. xii."

"The motion of the chyle throughout its course is to be ascribed to the contractility of its containing vessels, to their valves, and to the vis-a-tergo."

The force of their contraction is shown by the rupture of the thoracic duct from over-distention when a ligature is passed around it.[t] Tiedemann and Gmelin saw the thoracic duct contract from exposure to air.

"The use of the valve placed at the opening of the thoracic duct is probably not so much to prevent the influx of blood, as to modify the entrance of the chyle into the vein, — to cause it to enter by drops.

"By this contrivance, fresh chyle is prevented from having access to the blood so rapidly as to stimulate the cavities of the heart too violently and be imperfectly and difficultly assimilated.

"These *lymphatics*[u], which constitute the third part of the absorbent system, and resemble the lacteals in their structure and function, are much more, and perhaps, indeed, universally, diffused.[x] They arise principally from the cellular membrane, which we may call the grand bond of connection between the sanguiferous and absorbing system; but in great numbers likewise from the external common integuments[y], from the fauces, œsophagus," and all mucous membranes, "the pleura, peritonæum," and all serous membranes, from all excretory ducts, from arteries[z], and

[t] Sir Astley Cooper, *Med. Records and Researches.* A ligature of the thoracic duct does not necessarily deprive the body of nourishment, because there are sometimes two ducts, and sometimes one or more small trunks which unite with it or have a different termination in the venous system.

Dr. Magendie observed in the dog, that the contents of the thoracic duct flow but slowly; though more quickly during compression of the abdominal viscera.

On wounding it after a meal, he obtained half an ounce in five minutes, and they flowed for some time.

[u] "Consult, among others already and hereafter quoted, J. F. Meckel, *De vasis lymphaticis glandulisque conglobatis.* Berol. 1757. 4to.

And Al. Monro, filius, *De venis lymphaticis valvulosis.* Ib. same year. 8vo."

[x] Dr. W. Hunter, *Medical Commentaries,* P. i. p. 5. sq.

[y] "J. Elliotson has adduced new arguments showing that cutaneous absorption has been doubted of late without good reason, in his notes to the English translation of these *Institutions,* p. 129. 3d edit. 1820."

[z] Lymphatics may be injected from arteries. Lippi says that he finds many arise from arteries; and they probably originate from them as they do from every other part of the body. But to imagine they arise from arteries only is incorrect; and to imagine their sole function to be absorption from arteries, absurd. Dr. Magendie, however, attempts to revive the old opinion of lymphatics arising from arteries only and being destined to convey lymph from them.

from the substance of the "thoracic and abdominal viscera," in short, from every part, at least, where there is moisture.[a]

"Their origin is similar to that of the lacteals in the intestines, so that the radicle of each lymphatic absorbs the fluid from the surrounding spot, as from its territory, and propels it onwards.

"The lymphatics," like the lacteals, "have double valves, set more or less thickly in different parts; they almost all enter conglobate glands," perfectly similar to the mesenteric, diffused throughout the body, and aggregated in some situations, as in the groins and axillæ: "those lymphatics which are contiguous to each other anastomose here and there, and those found on the surface of certain viscera, as the lungs, liver, &c., form a most beautiful network." In the extremities, they run in two sets, — one deep-seated and accompanying the arteries, the other superficial and accompanying the subcutaneous veins.

"Besides other aids to their functions, evident from what has already been said, no inconsiderable assistance is derived from the combination of great strength with thinness of their coats by which they are enabled to support a heavy column of quicksilver. In the limbs, especially, the motion of the muscles, pressing them on every side, is highly useful in increasing their power."

Dr. Carson argued that the thoracic vacuum, which is explained in the chapter on respiration, would not only draw the blood along the veins, but draw it into their open mouths, thus being an agent of absorption. He concluded that the blood of the corpora cavernosa penis enters the veins in this way, but, as the lymphatics only were believed the organs of absorption, properly so called, when he first wrote, he had not a more extended idea of the co-operation of the vacuum in producing venous absorption. It must, however, evidently extend to every absorbing vein, and if the veins absorb generally, as some now believe, it must be general. As the great trunk of the absorbents terminates in a vein, they must be circumstanced in this respect exactly like veins, and equally subject to the influence of the thoracic vacuum. Indeed, Dr. Barry, in a work quoted in the chapter on respiration, found that while a cupping-glass was applied over a wound to which poison was applied, no ab-

[a] "Mascagni, tab. i. ii. iii.
T. Gottl. Haase, *De vasis cutis et intestinorum absorbentibus*, &c. Lips. 1786. fol. tab. i."

sorption occurred, no poisonous effects ensued; nor did they, even for some time afterwards; and when they became apparent, they instantly subsided on the re-application of the glasses. The pressure of the rim of the glass, he says, was not the cause of the non-appearance of poisoning, because if the deleterious substance was passed under the skin beyond the boundary of the glass, no ill effect occurred as long as the glass remained over the wound: an incision between the site of the poison and the rim destroyed the efficacy of the glass.[b] Yet others have found the same result from the cupping-glass pressed down and not exhausted, and even from the pressure of a solid body.[c]

Dr. Barry's experiments, however, would not prove that atmospheric pressure is the cause of absorption: they would merely show its co-operation, and that the propulsive powers of the absorbents are insufficient when opposed by the removal of it. Pecquet, nearly two centuries ago, considered whether the chyle was absorbed by suction; and concluded against the opinion, by observing, that, if a ligature was placed upon the thoracic duct or the lacteals of the mesentery, and all effect of vacuum thus prevented, the lacteals swelled on the intestinal side; therefore, said he, "non trahitur chylus sugiturve."[d]

The pressure of ordinary respiration and of muscular efforts is also seen to drive the chyle forwards in the lacteals.

"But their principal action, by which they take up fluids more or less rapidly, eagerly absorbing some and absolutely rejecting others[e]," like the lacteals, "depends upon the peculiar modifica-

[b] *Experimental Researches*, p. 102. The application of a vacuum in poisonous wounds has been recommended from the days of Hippocrates to those of Dr. Parry (*Cases of Tetanus and Canine Hydrophobia*), but its effects never shown so beautifully as by Dr. Barry. He recommends that the cupping-glasses should be first applied for an hour; that, the suppression of absorption for some hours being thus ensured, the part should be excised, and then the glasses re-applied to remove any portion of the poison that may remain, for the vacuum was found to extract some of the poison.

[c] See the translation, by Drs. Hodgkin and Fisher, of Dr. Edwards's work, hereafter quoted, p. 401. sq.

[d] *Dissertatio Anatomica de circulatione sanguinis et chyli motu*, p. 76. Paris, 1651.

[e] "On this remarkable difference consult T. Fr. Lucr. Albrecht, *Commentatio* (honoured with the Royal Prize) *in qua proponitur recensus eorum alimentor. et medicaminum, quibus, sive tubo alimentario sint ingesta, sive communibus corporis integumentis applicata, ingressus in systema vasor. sanguifer. aut concessus a natura, aut negatus sit.* Gotting. 1806. 4to."

tion of their vitality, and is acribed by the very acute Brugmans to a certain *vita propria.*[f]

"A great part of these lymphatics terminate in the thoracic duct; not, however, those of the right arm, the right side of the neck, the right lung, and the right portion of the diaphragm and liver, which terminate in the subclavian vein of the same side." Many other connections have been seen between absorbents and veins. Mr. Bracy Clarke discovered communications in the horse between the thoracic duct and lumbar veins[g], and Mr. Abernethy, Steno, Seiler, Mertrud, &c. traced lymphatic vessels to veins; Wepfer traced the absorbents of the broad ligaments into the hypogastric veins; Nuck, those of the arm into the lumbar veins; Lobstein, those of the spleen into the vena portæ; Tiedemann and Gmelin, like many before them, have propelled mercury into the vena portæ by absorbents; Mr. Cruikshanks long ago remarked, that, in animals destroyed by violence, the lymphatics about the spleen and in the cavity of the abdomen, in peritoneal inflammation sometimes the lacteals, and in peripneumony the lymphatics of the lungs, are tinged with blood, though no extravasation has occurred, and therefore he believed that lymphatics arise from the internal surface of arteries and veins[h]; the connection of the lymphatics with the veins, in the four classes of vertebrated animals, has of late years been demonstrated by Lippi, Fohmann, and Louth, and in the Anatomical Museum of Heidelberg are numerous beautiful specimens, showing this fact[i]; Lippi[k] has shown that the absorbents of the abdomen terminate abundantly in the branches of the vena portæ, as well as in the iliac, spermatic, renal, lumbar veins, &c. in the venous trunks, and in the veins issuing from conglobate glands, and become continuous with the capillary veins; indeed, that many terminate in the very pelvis of the

[f] "Conr. Jer. Ontyd (Præsidente Seb. Just. Brugmans), *De causa absorptionis per vasa lymphatica.* Lugd. Bat. 1795. 8vo. p. 45.

v. Al. Van Hees, *De causa functionis absorbentis systematis lymphatici.* ib. 1817. 4to. p. 38."

[g] Rees's *Cyclopædia:* Anatomy, Veterinary.

[h] *On the Absorbents,* p. 50.

[i] Mr. Coulson's edition of Mr. Lawrence's translation of Blumenbach's *Manual of Comparative Anatomy,* p. 172.

[k] *Illustrazioni fisiologiche e pathologiche del sistema linfatico-chilifero mediante la scoperta di un gran numero di communicazioni di esso col venoso,* par Regolo Lippi. Firenze. 1825.

kidney. These terminations explain circumstances which have led many to believe in absorption by veins, and even by veins only, and some to believe in the existence of other canals between parts. Such are the extreme rapidity with which fluids taken into the stomach are discharged by urine: the existence in the urine, but not in the contents of the thoracic duct, of certain articles which have been swallowed, as prussiate of potass: and the existence in the blood, and not in the thoracic duct, of others: and again the detection of others in the urine, and not in the blood, saliva, or nasal mucus.[l] In Tiedemann and Gmelin's experiments, among a variety of substances taken, coloured, odorous, or saline, very few could be detected in the chyle, but many were found in the blood. Raspail says, "The milk of women and other females almost always contains the vegetable juices of their food unchanged, although these are not to be found, I suspect, in the chyle; consequently, I should be inclined to admit that unknown connections exist between the breasts and the mucous surface of the stomach. I should say the same respecting the liver, pancreas, and spleen."[m] Three ounces of diluted alcohol were given by Dr. Magendie to a dog; in a quarter of an hour the blood of the animal had a decided smell of alcohol; the lymph (of the thoracic duct) had none.[n]

Dr. Magendie relates two experiments in which a decoction of nux vomica, introduced into the alimentary canal, produced its usual effects, notwithstanding the thoracic duct was tied and ascertained to be single. In fact, Sir Everard Home, many years ago, found substances to be taken into the circulation and into the urine from the stomach, though the thoracic duct was tied.[o] In a similar experiment, instead of the thoracic duct being tied, Dr. Magendie separated the portion of intestine containing the solution from the body, except in one artery and one vein. In another experiment, not only was every part of a limb separated from the body except the large artery and vein, but even these were cut asunder, quills having been previously introduced into them and fixed to carry on the circulation, and yet some upas plunged into the paw of the animal exerted its peculiar influence, which besides was suspended and permitted at pleasure by compress-

[l] Dr. Wollaston, *Phil. Trans.*, 1811.

[m] l. c. p. 357.

[n] *Précis de Physiol.* t. ii. p. 202. sq.

[o] *Phil. Trans.* 1811.

ing or liberating the vein under the finger and thumb.[p] Dr. Segalas cut a portion of living intestine from the rest of the canal, and passed a ligature around its blood-vessels, leaving the absorbents free, and introduced a solution of nux vomica for an hour without ill effect: he then liberated the vein, and the animal was poisoned in six minutes. Dr. Magendie mentions the following experiments, which, if to be depended upon,

[p] When the poison was placed in a wound, it might contaminate the blood without being taken up by absorbing extremities of vessels; and, if Magendie is right in believing that fluids soak through even *living* solids, we see how very readily it might all reach the blood. It is universally known, that, *after death*, fluids penetrate through the various textures of the body;—the aqueous humour diminishes in the eye, which consequently becomes flat, the intestines near the gall-bladder become yellow, and water poured into the stomach or intestines exudes. (A. Kaau, *Perspiratio dicta Hippocrati*, 565.)—Hence, especially in a hot atmosphere, if the examination of a dead subject is long delayed, parts may become so dyed with imbibed blood, that their redness may be, and often is, mistaken for inflammation. (See an important paper by Dr. John Davy, *Med. Chir. Trans.* vol. x.; also the more recent statements in Dr. Andral's *Précis d'Anat. Pathologie*, t. i. p. 63. sqq.)—Dr. W. Hunter contended that this imbibition occurs also during life, although not in the case of blood-vessels, and others admitted it. (*Med. Commentaries.*)—Dr. Magendie supports the same opinion. After separating a blood-vessel from the surrounding cellular membrane, and laying tincture of nux vomica upon it, the animal was poisoned, and the blood within tasted bitter; ink, placed in the pleura of a young dog, dyed, in less than an hour, the pericardium, heart, and intercostal muscles. Dr. Fodera introduced a solution of prussiate of potass into the pleura, and of sulphate of iron into the abdomen, of a living animal, when the two fluids became blue by union at the diaphragm, in five or six minutes, and instantaneously if a galvanic current was established. (*Journal de Physiologie*, t. iii.)—Still there is not the slightest reason to imagine that the *natural* fluids of parts penetrate their substance during *life* and in a *sound* condition. (See Hewson's arguments against transudation, *Experimental Inquiry*, p. ii.)—Dr. Magendie found absorption (of poisonous matters, for example, applied to surfaces) greatly impeded on rendering the vascular system turgid by injecting water into the veins, and equally accelerated on lessening the repletion by blood-letting. We should expect that the greater the repletion of the sanguineous system, the more difficulty must the contents of the absorbents have to advance, and *v. v.*; and from the wise arrangements observed in every function, we should conceive, that, supposing absorption a vital action, (as I cannot but believe it to be, as soon as a substance has fairly entered the vessel perhaps by mere physical attraction,) the vessels would be less disposed to propel their contents in proportion as repletion exists. How it favours, as Dr. Magendie fancies, the idea of absorption being a mere imbibition through the coats of the absorbents, — a notion unsupported and contradictory to established facts, — I cannot see. (In this I fully agree with Dr. Bostock, *An Elementary System of Physiology*, vol. ii. p. 587. sqq.)

would perhaps show that heterogenous fluids are taken up by absorbents running to veins pretty readily, though rejected by the lacteals which run to the thoracic duct. In the horse, the usual contents of both the large and small intestines are mixed with a large quantity of fluid that gradually decreases towards the rectum, and is therefore absorbed as it passes along the canal. Now, Flandrin, having collected the contents of the lacteals, did not find them smell like this intestinal fluid, whereas the venous blood of the small intestines had a taste distinctly herbaceous; that of the cæcum a sharp taste, and a slightly urinous smell; and that of the colon the same qualities in a more marked degree: the blood of other parts presented nothing analogous. Half a pound of assafœtida dissolved in the same quantity of honey was given to a horse, which was afterwards fed as usual, and killed in sixteen hours. The smell of assafœtida was perceptible in the veins of the stomach, small intestines, and cæcum; but not in the arterial blood, nor in the lymph.[q] But similar experiments, with opposite results, have been made by others. John Hunter, after pouring water coloured by indigo into the peritoneum of an animal, saw the lymphatics filled with a blue fluid. In the hands of MM. Magendie, Flandrin, and Dupuytren, this experiment likewise has failed. Magendie does, however, allow, that, in a woman who died with a collection of pus in the thigh, the surrounding lymphatics were distended with pus to the size of a crow's quill; — a pretty decisive proof that lymphatics absorb, as the lymphatics are not said to have been diseased. The absorbents of fish have no valves except at their termination in the red veins, and may therefore be injected from the principal trunks: the injection passes out of the mouths of the absorbents in numerous streams, and especially on the back, if the skate is employed; — another decisive fact. Peyer, Fallopius, and Kerkring saw bile in lymphatics about the liver. Seiler, Walter, and Lippi, have injected absorbents from various excretory ducts. Mr. Kiernan always readily injects them, and sometimes even the thoracic duct, from the hepatic ducts of the liver. Oudmann and Schreger have more lately made many experiments, and proved absorption by the lymphatics, though they have not proved it does not take place also by veins. Down to Boerhaave and Haller the doctrine that the lymphatics absorb was maintained, and it

[q] *Précis de Physiol.* l. c. t. ii. p. 267.

was first seriously attacked by Dr. William Hunter. Dr. Monro secundus soon afterwards did the same, and commenced a very acrimonious quarrel with Dr. William Hunter for the honour of priority of attack. Dr. Baillie expressly states, that Dr. Hunter had delivered such opinions six years before Dr. Monro professes to have made his discovery, and the world has generally given priority to Dr. Hunter. Dr. Monro had also an equally acrimonious dispute with Mr. Hewson for the honour of the discovery of the lymphatics in fish, but the Royal Society adjudged Hewson the Copley medal in 1769 for the discovery. It is amusing to reflect that the very doctrine, for the honour of having first attacked which so much violence was shown, is now again in high favour with some; and that Dr. Monro would be now lauded had he shown that Dr. Hunter only had attacked it. John Hunter deposited various fluids in the intestines; but, although he found manifest traces of them in the absorbents, he could discover none in the mesenteric veins. In the experiments of Oudmann and Schreger, substances were found in the lymphatics, and not in the veins.

It may be difficult not to suppose that both parties were inaccurate in some of their negative observations.

This appears certain;—1. That the lacteals absorb chyle; and usually, but not invariably, nothing else. 2. That the lymphatics absorb; and, as they terminate so abundantly in veins, and a lymphatic running to a minute vein has just the same right to be called a vein as a lymphatic, we may say that the veins absorb. 3. That lymphatics do not absorb quite indiscriminately; and those which run to veins, perhaps, absorb more indiscriminately than those which continue on as lymphatics and run to absorbent ganglia or glands.

"From the universal existence of the lymphatics, and especially from their great number on the surface capable of absorbing fluids from without, the heterogeneous nature of the lymph must be obvious; and this is further proved by accurately examining it in different parts of a subject; *v. c.* that contained in the hepatic or splenic lymphatics is perfectly different from that in the uterine.

"We will enumerate the principal fluids which are continually absorbed during health, to say nothing of many different kinds of substances taken up during disease. There is, besides the chyle separated from the fæces in the small intestines, the halitus of the cavities, properly so called, especially that of the fauces and of all the mucous membranes, the more watery part of those secreted fluids which are retained for some time in their ducts, *v. c.* in the breast, the vesiculæ seminales, the gall-bladder, &c. and not a small portion of the stillatitious fluids which are applied to the common integuments. [r]

" The solids, after performing their purpose in the economy, insensibly melt away and are absorbed, as is proved by the absorption of the greater part of the thymus gland during infancy, of the roots of the first teeth, and of the alveoli after the second teeth have fallen out. The constant change of the whole osseous system, arising from the insensible renovation of the bony matter, of which we have treated elsewhere professedly[s], may also be adduced.

" It is therefore evident, since so great a variety of matter is absorbed, and at the same time nothing crude or improper allowed to enter the blood, that there is a necessity for some peculiar medium to previously subact and assimilate the various substances.

" It appears to be the chief office of the *conglobate glands*, which constitute the last part of the absorbent system, to prevent the ill effects upon the heart of the improper admixture of crude fluid [t] with the blood, by assimilating the extremely various fluids more and more to an animal nature, by retarding their motion, and perhaps also by superadding to them some fresh-secreted fluid."

This will appear from the following information given us by chemists: —

The fluid collected from the thoracic duct scarcely differs from milk. It is opaque and white; without smell; sweetish and

[r] " Consult, among others, Valer. Lud. Brera, *Anatripsologia;* fourth edition. Pavia, 1799. 2 vols. 8vo.

A. J. Chrestien, *De la méthode iatroliptice.* Montpell. 1803. 8vo. In German, Gotting. 1813. 8vo."

[s] " Decade 1. *Collection of the crania of different nations,* p. 27."

[t] " If we consider the winding course which nature has provided for the purpose of changing and assimilating the absorbed fluids before their admixture with the blood, and, on the other hand, the dreadful symptoms, such as palpitation, convulsions, &c., which ensue upon the *artificial infusion* of a minute portion of any mild fluid into the blood, we shall be inclined to believe that those absorptions, which Haller (*De c. h. Funct.* vol. i. p. 281. sq.) endeavours to prove are accomplished by the veins, do really take place by means of the lymphatic system."

alkaline; and separates, like the blood, into a solid and a serous portion: the former is insoluble, and rises to the surface sometimes covered with an oleaginous layer. It contains the same salts as milk, and is affected by re-agents in the same manner.[u] If formed from vegetable food only, it is nearly transparent, may be kept weeks or even months without putrefying, and affords a faintly pink coagulum. If from animal food, it is white and opaque, begins to putrefy in a few days, affords an opaque coagulum which acquires a more marked pink hue by the influence of the atmosphere, and throws upon its surface a white creamy substance. The former gives three times as much carbon as the latter; but the latter, being so much richer gives much more carbonate of ammonia and heavy fixed oil, when subjected to the destructive distillation.[x]

Chyle collected from lacteals is whiter, coagulates less perfectly, or not at all, and does not acquire a red colour by exposure to the air[y], so that sanguification proceeds gradually as the chyle passes towards the left subclavian vein.

Although some albumen is discovered actually in the duodenum, and, as Dr. Prout allows, even in the stomach if animal food has been taken, and some fibrin in the first lacteals, the contents of the absorbents are found to possess more and more of these substances in proportion to their progress towards the left subclavian vein. The chyle contains a certain fatty matter, which is considered as *incipient albumen*, and, in proportion as this decreases, does the quantity of fibrin and albumen increase.

The pink colour, acquired by the coagulum of chyle when exposed to the atmosphere, shows the use of the lungs in sanguification.

White globules exist in the chyle even at a very early period of its formation, and these most probably it is that become co-

[u] Raspail, l. c. p. 356.

[x] Dr. Marcet, *Med. Chir. Trans.* vol. vi. His observations were of course made upon the fluid obtained from brutes. Yet MM. Macaire and Marcet, of Geneva, say that the chyle as well as the blood of herbivorous and carnivorous animals is identical in its ultimate analysis; that whatever food an animal habitually eats, the quantity of nitrogen is essentially the same in both the chyle and blood. There is less nitrogen, they say, in chyle than in blood. *Mém. de la Soc. de Phys. et d'Hist. Nat. de Genève*, t. v. p. 389.

[y] Emmert, *Annales de Chimie*, t. lxxx.

[z] Dr. Prout, in Thomson's *Annals of Philosophy*. 1819. p. 274.

loured when the chyle grows pink by the action of the air. There are also much larger white particles in the chyle, appearing to be formed of the caseous-like and oily principles, and, being insoluble in the serum, naturally assume the globular form.[a]

Dr. Marcet had reason to believe that the appearance of creamy matter floating in the serum of blood occurs most frequently when the food is chiefly animal, and when therefore rich chyle is poured into the blood faster than it can be assimilated. The serum at first appears milky; but it gradually becomes clear, from the creamy matter separating and rising to the surface.

The coagulum of the fluid of the thoracic duct is much less firm than that of blood; and after a few days, if allowed to remain in a separate vessel, it passes almost entirely to the fluid state. Vauquelin regards it as unfinished fibrin, something between albumen and fibrin.

I once saw a young married woman whose urine contained very large coagula of chyle. She always dined at noon. In the evening the coagula were white; in the morning pale with pink streaks. After fasting twenty-four hours at my request, the coagula still appeared in the urine, extremely pale, and showing more pink streaks: and this is the more worthy of notice, as others, we see, have found chyle and lymph to grow reddish from abstinence (p. 124.) She had been some months in this way, was in very fair health, and had a great appetite, and perhaps some other general symptoms of diabetes; but there was no sugar in the urine. Notwithstanding the fluid discharged seemed to present as much coagulum as it did urine, the quantity of chyle proved on drying to be very minute, and from its looseness to have been extremely distended by the urine. As this was a state of disease, I draw no inference from the case respecting the time necessary for the change of chyle to blood. She would not allow me to take any blood from the arm for observation.

Similar cases have been published by Dr. Prout[b], and there may be several on record[c], but the only one besides of which I have read is quoted in Shenkius. "I saw," says the author whom he quotes, (in Castro Itri, Comitatus Sundorum,) "a young man, thirty years of age, who daily made a considerable quantity of urine, depositing a white substance like the curd of milk, sufficient to fill

[a] Dr. Prout, in Thomson's *Annals of Philosophy*. 1819. p. 275.

[b] *A Treatise on Gravel*, &c. 2d ed. 1825.

[c] See *Ephem.*, Dec. I. ann. i. obs. 89.

a common *pot de chambre*, besides the urine which was above it. He was in perfect health, not experiencing the slightest ill effect."[d]

Lymph from the hind extremities of a horse was found by Emmert to be white, with straw-coloured globules, to contain rather less albumen, to coagulate more imperfectly, and become less easily red on exposure to air, than the contents of the thoracic duct.[e]

According to the recent observations of Tiedemann and Gmelin, the chyle has no fibrin, so as scarcely to coagulate, nor any red particles, before it passes through the mesenteric glands; but immediately afterwards, and especially after it is mixed with the lymph of the spleen,—a fluid abounding with them and fibrin,—presents both, and still more copiously than the lymph of the extremities.

No fatty matter is discoverable in the lymph, nor indeed in the chyle if the animal fasts or takes food destitute of fat. The fatty matter is merely diffused through the chyle, and found even in the blood after butter has been eaten.

Ligature of the choledochus they found to augment the quantity of fibrin and red particles, and to diminish that of fatty matter in the chyle.

Dr. Prout has just published his belief in something like the opinion always entertained by Blumenbach, that the lymph, on account of being a highly animalised fluid, contributes greatly to the formation of blood. He goes farther than Blumenbach: yet perhaps Blumenbach's opinion may, in reality, though not

[d] *Observat. Med. rariores*, lib. iii. obs. 27. Dr. Charles Smith, of New Jersey, relates an example of ascites in a boy twelve years of age, where the fluid accumulated was of a chalky white colour, had pretty nearly the smell, taste, and appearance of milk, and threw up good cream after standing a night. Between seven and eight quarts of this were twice removed by tapping. *Philos. Mag.*, vol. ix. p. 168.

Shenkius is generally thought a credulous collector of incredible cases, and no doubt some of his histories as well as of his opinions are ridiculous. But careful modern observation discovers facts precisely similar to the greater number that he has collected. I might have doubted the history just related, more especially the good health of the patient, had not the case of the woman occurred to me. For example, he gives some instances of black urine made by persons in perfect health, and Dr. Marcet has published two such (*Transactions of the Medical and Chirurgical Society*, vol. xii.). Dr. Prout showed me a specimen of urine from one of these, and a specimen of blue urine, containing indigo.

[e] See also Vauquelin, *Annales de Chimie*, t. lxxxi. 181.

in words, amount to his.[f] Dr. Prout conceives that "*a sort of digestion is carried on in all parts of the body, to fit for absorption and future appropriation those matters that have been already assimilated.*" His chief reasons for this opinion are — 1. That, if the contents of the absorbents were really and wholly excrementitious, they would be rejected, and not poured into the blood. 2. If they are highly animalised, we have a reason for their admixture with the crude chyle before it is poured into the blood. 3. The gradual developement of the staminal principles of organised bodies, by repeated organising processes, agrees with the general truth of the operations of nature being never abrupt, but always slow and gradual; and matters already assimilated to the body must be better adapted for its immediate use than the imperfectly assimilated chyle. 4. Many animals can and do live for a considerable time on their own bodies.[g]

I agree entirely in these reasons, and consider it a great mistake to regard the lymph as a collection of excrementitious matters.

[f] Blumenbach's words are, — " Since the blood is a peculiar fluid, various means are required to assimilate the foreign fluids which pass to the thoracic duct. We must remember that a great part of the lymph has been derived from the substance of the viscera and other soft parts formerly secreted from the blood, and therefore already imbued with an animal nature." (*Inst. Physiol.*, §§ 446. 448.)—Raspail also says,—" Lymph is alcaline, and, in fact, to be considered as a variety of chyle or colourless blood." p. 455.

[g] *Bridgewater Treatise.*

Dr. Magendie denied the existence of lymphatics in nearly all birds, but has been amply refuted by Dr. Louth and many others. Birds have few lymphatic ganglia; and amphibia and fish still fewer (Blumenbach's *Manual of Comp. Anat.* translated, p. 174.); and invertebrate animals have no lymphatic vessels. These, therefore, are considered a refinement of organisation, and lymphatic ganglia a still greater. Professor Müller of Bonn has lately discovered in the lymphatic system, under the skin of the frog, and several other amphibia, *lymph-hearts*, pulsating regularly, though not simultaneously either with each other or the blood-heart, and destined to advance the lymph in its vessels. *Phil. Trans.* 1833.

A short account of the first discovery of the absorbent system may be acceptable at the close of this section.

Hippocrates knew that the nutritive portion of the contents of the alimentary canal was conveyed by certain vessels to the system. Erasistratus actually saw the lacteals containing chyle — ἀρτηριας, γαλακτος πληρεις. From Galen we learn that they were known also to Herophilus. From the year 150 to 1622 no advance was made, except that in 1563 Eustachius discovered the thoracic duct, but he remained ignorant of its use. In 1622, Aselli in Italy saw the lacteals by chance, when demonstrating the recurrent nerves to some friends. Thinking they were nerves, he at first paid no attention to them; but, soon observing that they did not pursue the same course as the nerves, and "astonished at the novelty of the thing, he hesitated for some time in silence," while all the circumstances of the controversy and quarrels of anatomists passed before his view. He had by chance been reading Costæus on this subject the day before, and, in order to examine the matter further, he "took a sharp scalpel to cut one of those chords, but had scarcely struck it when," he continues, "I perceived a liquor white as milk, or rather like cream, to leap out. At this sight, I could not contain myself for joy, but, turning to the by-standers, Alexander Tadinus and the senator Septalius, I cried out Εὕρηκα! with Archimedes, and at the same time invited them to look at so rare and pleasing a spectacle, with the novelty of which they were much moved. But I was not long permitted to enjoy it, for the dog now expired, and, wonderful to tell, at the same instant the whole of that astonishing series and congeries of vessels, losing its brilliant whiteness, that fluid being gone, in our very hands and almost before our eyes, so evanished and disappeared, that hardly a vestige was left to my most diligent search." The next day he procured another dog, but could not discover the smallest white vessel. "I now," he says, with the same admirable *naïveté*, "began to be downcast in my mind, thinking to myself that what had been observed in the first dog must be ranked among those rare things which, according to Galen, are sometimes seen in anatomy." At length he recollected that the dog had been opened "athirst and unfed," and therefore opened a third, after feeding him "to satiety." "Every thing was now more manifest and brilliant than in the first case." He gave his whole attention to the subject, and was so diligent that not a week, or certainly not a month, passed without a living dissection of dogs, cats, lambs, hogs, and cows; and he even bought a horse, and opened it alive. "A living man, which Erasistratus and Herophilus of old did not fear to anatomise, I *confess* I did not open."

Notwithstanding this discovery of distinct chylous vessels, a large number of high authorities adhered firmly to the old opinion of Galen, that they were only mesenteric vessels. "There is not one among the doctors," we read in a letter of Thomas Bartholin, written at Montpellier, during his journey to Italy, "who acknowledges the lacteal veins, so wedded are they to the authority of Galen, for which they contend as *pro aris et focis*, and disregard the experiments of the moderns." Unluckily, he did not trace the lacteals to the left subclavian vein, but fancied they went to the liver, distributing the chyle through it for sanguification; this organ, according to the established doctrine, receiving the chyle from the mesenteric arteries and veins to convert it into blood.

In 1649, Pecquet, a physician at Dieppe, was removing the heart of a dog, when he noticed a quantity of white fluid pouring from the upper cava mixed with blood. He at first thought he had opened some strange abscess; and, after pressing first upon one part and then upon another, he compressed the mesentery, whose lacteals were full of chyle, when instantly a large quantity of this poured from the superior cava. He traced the lacteals to the thoracic duct, and thus overthrew the doctrine of the liver being the great seat of hæmatosis.

Of course, there was as great an outcry against this innovation in doctrine, as there had been against the existence of lacteals, and even Harvey, who was now nearly eighty years of age, could not at once loosen himself from the bonds of early prejudice, and Thomas Bartholin, whose eyes had always been open to improvement in medicine, still thought that perhaps the finer parts of the chyle went by the new ducts to the chest, " while the grosser, needing a larger concoction, enter the liver."

About eighty years after the discovery of Asellius, Rudbeck, professor at Upsal, or Thomas Bartholin who was professor at Copenhagen and son of Caspar Bartholin, or Joliff, an English student, discovered the lymphatics.[h] Rudbeck says, he first happened to see them while examining the hemorrhoidal vessels of a dog, Jan. 27. 1651. He published in 1653. Bartholin, that he first chanced to see them while dissecting a dog, Dec. 15. 1651, but did not notice them particularly till Feb. 28. 1652. He published in 1653. As to Joliff, we only read in Glisson, that, at the beginning of June, 1652, going to Cambridge for his doctor's degree, he showed them to Glisson, who was then professor of medicine. Glisson published in 1654; Joliff never published, and probably had learnt the continental discovery while travelling. Bartholin is thought to have received a hint of Rudbeck's discovery. Haller gives the discovery to Rudbeck.

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[h] See an interesting history of these discoveries, by Dr. Meigs, *Philadelphia Journal*, 1825. No. 2. New series.

CHAP. X.

THE BLOOD.

The fluid into which the chyle and lymph are converted, is blood. "The *blood* is" a slightly alcaline fluid, of a red colour ; " of a peculiar odour ; its taste is rather saline and nauseous ; its temperature about 96° of Fahrenheit ; it is glutinous to the touch ; its specific gravity, though different in different individuals, may be generally estimated as 1050, water being 1000." Blood from arteries is florid, and from veins of a dark red which the translucence of the venous coats renders bluish when seen through them : and the specific gravity of the former is said by Dr. John Davy to be 1049, and of the latter 1051.[a] " When fresh drawn and received into a vessel, it exhibits the following appearances[b] :—

" At first, especially while still warm, it emits a vapour which," " if collected in a bell glass, forms drops resembling dew, of a *watery* nature, but affording a nidorous smell, which is most remarkable in the blood of carnivorous animals, is peculiar, and truly animal. Much of this watery liquor still remains united with the other parts of the blood, hereafter to be mentioned.

" In the mean time the blood " " begins to separate into two portions. A coagulum is first formed, from the surface of which exudes, as it were, a fluid of a yellowish slightly red colour, denominated *serum :* the more abundantly this exudes, the greater is the contraction of the glutinous coagulum, which has received the appellations of *crassamentum ;* and, from some resemblance to the liver in colour and texture, of hepar sanguineum ; of placenta ; and, from the circumstance of its being surrounded by the serum, of insula."

Some have thought that heat is evolved during its coagula-

[a] *Journal of Science and Arts,* No. iv.

[b] " J. Martin Butt, *De spontanea sanguinis separatione.* Edin. 1760. 8vo. reprinted in Sandiford's *Thesaurus,* vol. ii. J. H. L. Bader, *Experimenta circa sanguinem.* Argent. 1788. 8vo."

tion[c]; others have denied this.[d] M. Raspail says that the temperature falls.[e]

"The crassamentum may, by agitation or repeated ablution, be easily separated into two constituent parts, — the *cruor*, which gave to the blood its purple colour — and the *fibrin*, which on washing is forsaken by the cruor, and called, from its greater solidity, the basis of the crassamentum.

"Besides the watery fluid first mentioned, these are the three constituents of the blood, viz. the *serum*, the *cruor*, and the *fibrin*, of each of which we shall presently treat more particularly. These, however, while perfectly recent, and in possession of their native heat, are intimately mixed, and form an equable, homogeneous fluid. Their relative proportion is astonishingly diversified, according to age, temperament, diet, and similar circumstances which constitute the peculiar health of each individual."

The quantity of blood in a well-formed adult is estimated by "Allen, Mullen, and Abildgaard, at little more than 8 pounds; by Harvey, at 9; Borelli, 20; Haller, 30; Riolan, 40; Hamberger, 80; and Keil, 100. The former are evidently nearer the truth." M. Le Canu says, that the quantity of its *water*, in a healthy person, varies from 853·135 to 778·625 in 1000 parts, and the medium quantity is greater in females and in the phlegmatic temperament: of its *albumen*, from 78·270 to 57·890, and has no relation to sex, age, or temperament: of its *fibrin* dry, from 1·360 to 2·236, is the greatest in the young or middle-aged, in the sanguine temperament, and in the inflammatory state; least in the phlegmatic temperament, the aged, and under congestion or hemorrhage: of its *globules*, from 148·450 to 68·349 — being the most remarkable variation — is greatest in males, the same between the ages of twenty and sixty, much greater in the sanguineous than the phlegmatic temperament, and much less after losses of blood, which do not affect the quantity of the albumen.[f]

[c] Dr. Gordon, *Annals of Philosophy*, vol. iv. Scudamore, *An Essay on the Blood*, 1824. p. 68. sqq.

[d] Dr. J. Davy, *Journal of Science and Arts*, No. iv. [e] l. c. p. 361.

[f] *Journal de Pharmacie*, Sept. and Oct. 1831. In various diseases, Dr. Clanny, of Sunderland, and Dr. Stevens, have found the salts of the blood exceedingly deficient. In fevers, the proportion of water increases as the disease advances, and that of the salts diminishes; and it is said that, in the latter stages, the exhibition of neutral salts is very beneficial, as recommended by Boerhaave, Huxham, &c. in the early part and middle of the last century, and Dr. Stevens at present in his *Observat. on the healthy and diseased Properties of the Blood*. London, 1832. Dr. Priestley remarked that different specimens of blood differed in their susceptibility of change of colour from air. *Ph. Tr.* 1776.

The *blood*, according to M. Le Canu, consists of the following constituents: —

	1st Analysis.	2d Analysis.
Water - - - - -	780·145	786·590
Fibrin - - - -	2·100	3·565
Albumen - - - -	65·090	69·415
Colouring matter - - -	133·000	119·626
Crystallisable fatty matter - -	2·430	4·300
Oily matter - - - -	1·310	2·270
Extractive matter soluble in alcohol and water - - - -	1·790	1·920
Albumen combined with soda - -	1·265	2·010
Chloruret of sodium and potassium, alkaline phosphate, sulphate, and sub-carbonates - - -	8·370	7·304
Subcarbonate of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron - -	2·100	1·414
Loss - - - -	2·400	2·586
	1000·000	1000·000

When blood, venous or arterial, is immediately placed in the vacuum of an air pump [g], or coagulates in the air [h], or is received from a vein into pure hydrogen [i], it emits a large quantity of carbonic acid gas. Professor Brande obtained two cubic inches from every ounce of blood; Sir C. Scudamore, less than half a cubic inch from six ounces.[k] The quantity is said to be much greater after a meal, and much less if the blood is buffy.

[g] Vogel, *Annales de Chimie*, t. xciii.

[h] Professor Brande, *Phil. Trans.* 1818. p. 181.

[i] Dr. Stevens, *London Medical Gazette*, 1834, No. xxviii. Mr. Hoffman, id. 1833, No. xxvi.

[k] *Phil. Trans.* 1820. p. 6. l. c. p. 107.

Blumenbach, found, in 1812, that a small portion of the purest air, infused into the jugular vein, excited palpitations, drowsiness, convulsions; and, if the quantity was a little increased, even death ensued. (*Medicin. Biblioth.* vol. i. p. 177.) Bichat observed the same effects in his experiments. (*Journal de Santé, &c. de Bordeaux*, t. ii. p. 61.) But Dr. Magendie stated, in 1809, to the Institute, that this assertion is incorrect. If air is injected rapidly, the animal screams and dies in a moment: but if slowly, he informs us that no inconvenience results, and that some animals bear the injection of enormous quantities without perishing. (*Précis Elémentaire de Physiologie.* 2d edition, 1825. t. ii. p. 433. sqq.) Dr. Blundel injected five drams into the femoral vein of a very

Chevreul, Lassaigne, and others discover a yellow colouring matter like that of the bile and urine. Dumas and Prevost and others discern something like urea, which M. Raspail suggests may be the effect of their experiments, as Woehler discovers urea to be a cyanite of ammonia, and capable of artificial production by passing cyanogen (bicarburet of nitrogen) through ammoniacal gas.

"The *serum* is a peculiar fluid, the chief cause of the viscidity of the blood, and easily separable by art into different constituent principles. If subjected to a temperature of 150° Fahr., a portion is converted into a white scissile substance, resembling boiled white of egg," and is in truth albumen; the watery portion which remains was termed serosity by Cullen, and contains various substances.

If mixed with six parts of cold water, serum does not coagulate by heat.

Under the influence of the galvanic pile, soda collects at the negative wire, and the albumen coagulates at the positive, on account, M. Raspail says, probably, of the decomposition of the salts and also of the water, and the consequent oxygenation of every thing at the positive pole, where the oxygen collects; and

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small dog, with only temporary inconvenience, and subsequently three drams of expired air even without much temporary disturbance. (*Med. Chir. Trans.* 1818, p. 65. sq.) Nysten has established that many gases soluble in the blood, as oxygen and and carbonic acid, may be thrown into the circulating system in very large quantity without serious inconvenience; while danger often ensues upon the introduction of those which are sparingly or not at all soluble in the blood. (Magendie, l. c.)

In the same way, if about 15 grains of bile are rapidly introduced into the crural vein of an animal, instant death occurs; but, if slowly, no inconvenience results. This quantity may be even rapidly injected into the vena portæ without injury, and so likewise may atmospheric air, probably because the extreme subdivision of the vessel acts like slowness of introduction, — causes the complete diffusion and dilution of the bile, and solution of the air, before it reaches the heart.

If warm water is introduced (an equal quantity of blood being first removed, to prevent over distension) mere debility ensues, proportionate to the quantity; but if oils, or mucilages, or an inert impalpable powder, are injected, life is at once destroyed by the obstruction of the minute ramifications of the pulmonary artery. (Magendie, *Journal de Physiologie*, t. i., and l. c. t. ii. p. 260.) Poisons act powerfully if injected into the veins; and, as will presently be mentioned, medicines, thus introduced, exert their specific powers on the different organs.

of the increase of temperature attending the decomposition of organised bodies.[l]

M. Le Canu gives the following analysis of serum:—

	1st Analysis.	2d Analysis.
Water - - - -	906·00	901·00
Albumen - - - -	78·00	81·20
Animal matter soluble in water and alcohol - - - -	1·69	2·05
Albumen combined with soda - -	2·00	2·55
Crystallisable fatty matter - -	1·20	2·10
Oily matter - - - -	1·00	1·30
Muco-extractive matter - -	—	—
Extractive matter soluble in alcohol and acetate of soda - - -	—	—
Hydrochlorate of soda and potash -	6·00	5·32
Sub-carbonate and phosphate of soda and sulphate of potass - - -	2·10	2·00
Phosphate of lime, magnesia, and iron, with sub-carbonate of lime and magnesia	0·91	0·87
Loss - - - - -	1·00	1·61
	1000·00	1000·00

The *cruor* consists of globules; and Mr. Hewson asserts that they have a nucleus and an enveloping coloured portion.[m] The nucleus is said to be colourless: perhaps about $\frac{1}{5000}$ of an inch in diameter, and the whole globule nearly one fourth larger.[n] M. Raspail says, that, though the form and dimensions of the particles are different in different species, and nearly the same in the same individual, they still vary within very narrow limits in individuals, and the dimensions in even the same drop of blood, especially if not examined immediately that the blood is taken from the vessels. In man, he says, they are from $\frac{1}{100}$ to $\frac{1}{200}$ of a millimètre, flat and circular. MM. Prevost and Dumas believe[o] that the internal portion is spherical, but the outer or vesicular, as Hewson noticed[p], flattened. The inner part, according to these

[l] l. c. 202.

[m] *Experimental Inquiries*, part. 3. p. 16. 1777.

[n] On these measurements consult *Phil. Trans.* 1818. Dr. Young's *Medical Literature*, p. 571. sqq. Prevost and Dumas, *Annales de Chimie*, Nov. 1821. Hodgkin and Lister, *Ph. Mag.* Aug. 1827. Particularly M. Raspail.

[o] l. c. Hodgkin and Lister find no nucleus.

[p] l. c. p. 8. sq. Hewson says, that dilution with water, or a change towards

enquirers, rolls in the outer, and, in the frog's web and bat's wing, at least, the whole particle is carried, steadily balanced, in the current of blood, sometimes flat, sometimes oblique, sometimes gently turning upon itself, and lengthening if driven into a vessel of diameter hardly sufficient for its admission; the old assertion of Reichel [q] being thus corroborated. Kalk, Treviranus, and others have noticed a rotatory motion of the entire particles, each at a distance from the other; and Professor Schultz of Berlin has confirmed their observations. But M. Raspail considers these motions as accidental and mechanical results, such as have deceived so many microscopic investigators. Mr. Bauer says he has discovered a third set of smaller colourless globules in the blood, $\frac{1}{2800}$ of an inch in diameter, which appear to belong to the fibrin, and are accordingly denominated lymph globules; and it is thought probable that the central globule of the red particles is the same, and thus really fibrin. Colourless globules gradually form also in serum.[r] The globules of pus also are asserted to form gradually, and it to be originally an homogeneous fluid.

The globules of the blood, independent of their covering of red substance, M. Raspail regards as mere particles of albumen not dissolved in the serum, and, after proving their albuminous nature, shows how albumen dissolved in an excess of concentrated hydrochloric acid forms minute, spherical, equal globules, in proportion as the decanted acid *spontaneously* evaporates, scarcely distinguishable from the globules of the blood. One takes breath while reading M. Raspail, after the strange and varying statements of so many experimenters, especially of those who use microscopes.

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putrefaction, makes the vesicles globular, and that farther putrefaction breaks them down. The effects of dilution with water are, according to Raspail, extension, sometimes spherical, sometimes elliptic, and at length complete solution.

[q] G. Chr. Reichel, *De sanguine ejusque motu experimenta.* Lips. 1767. p. 27. fig. 3. g. g.

[r] *Phil. Trans.* 1819. p. 2. sq. The globules of milk, healthy pus, and chyle, in different animals, are said by Prevost and Dumas to be of the same form and dimensions: and likewise those of the muscular fibre, and of albumen, when coagulated, for particles, we are told, are not previously seen in it. But Dr. Hodgkin finds the particles of pus to be quite irregular in size and figure, and those of milk, though globules, to be some twice, some only one tenth, the size of the particles of the blood. *Phil. Mag.* Aug. 1827, and translation of Dr. Edward's work. I shall refer to M. Raspail in the proper place.

If arterial blood is exposed to ammoniacal gas, it becomes of a cherry red; if to gaseous oxide of carbon, the deutoxide of azote, or carburetted hydrogen, of a violet red; if to carbonic acid, though covered by two inches depth of serum[s], azote, hydrogen, or protoxide of azote, of a brown red; if to arseniuretted or sulphuretted hydrogen, of a deep violet inclining to a greenish brown; if to hydrochloric gas, of a chestnut brown; if to sulphureous gas, of a blackish brown; and if to chlorine, of a blackish brown inclining to a greenish white.[t] These gases are of course partly absorbed or decomposed. The dark colour produced in arterial blood by carbonic acid or azotic gas takes place if blood is placed in vacuo[u], though less rapidly and deeply than if exposed to hydrogen gas, and in vacuo, though covered by two inches and a half of serum.[x] Arterial blood extravasated or included between two ligatures in an artery[y], nay, left in contact with oxygen, gradually acquires the same dark colour, and no oxygen will afterwards render it scarlet. Acids, if stronger than just enough to neutralise a weak salt, and alcalies, darken arterial blood. If deprived of all saline matter by washing, the reddest clot of blood becomes black, and will not grow florid by oxygen: whereas if saline matter is added, it becomes florid, even in an atmosphere of carbonic acid.[z]

Venous blood acquires a florid colour by exposure to oxygen or atmospheric air (and it does so even when covered by a bladder, provided this is moistened[a]), carbonic acid gas is formed, and an equal volume of oxygen gas disappears, and this the more if the temperature is high.[b] If exposed to nitrous oxide, it becomes of a brighter purple, and much of the gas is absorbed; carbonic acid gas renders it darker, and is a little absorbed: nitrogen and hydrogen have the same effect. Electricity blackens the blood, and, according to Dr. Stevens, the poison of the rattlesnake, and other poisons, though floating only in the air. Putrefaction makes the blood dark. Alcaline and some other neutral

[s] Dr. Priestley, *Ph. Tr.* 1776.

[t] Raspail, l. c. p. 361.

[u] Beccaria, who experimented at the request of Cigna. *Misc. Taur.* t. 1.

[x] Dr. Priestley.

[y] Hunter, *On the Blood*, p. 65. sq.

[z] Dr. Stevens.

[a] A layer of serum or milk does not prevent this change of colour, while a layer of water, saliva, and every other animal fluid, or oil, does. Dr. Priestley.

[b] Dr. Stevens.

salts, make venous blood florid[c]; and this, if added in considerable quantities, even when the blood is exposed, not to oxygen or air, but to a blackening gas.

Dr. Stevens seems to have proved that the colouring matter of the blood is really black, and acquires redness only by the action of the salts upon the hematosine; and that venous blood is of a dark red through the presence of carbonic acid, and but for the salts would be black. If blood is black from want of salts, very little of them will make it florid; if it is black from the presence of carbonic acid, azote, &c., the quantity of salts requisite will be proportionate to the quantity of the blackening agent. Oxygen indirectly renders blood florid, by removing the carbonic acid gas, and thus allowing the salts of the serum to brighten it; for if these are washed away, we see that oxygen has no effect, and we see that in proportion to the disappearance of oxygen is carbonic acid evolved. The same interchange of carbonic acid takes place in hydrogen, and the blood remains black; but then hydrogen blackens blood as well as carbonic acid. It is possible that oxygen may have the property of making blood florid, just as hydrogen, nitrogen, carbonic acid, &c. have to make it dark. But if it have, still it does not make the blood florid unless salts be present, and carbonic acid always appears; and when blood is darkened by putrefaction, so that air will not make it florid, the addition of most neutral salts instantly brightens it. Such are the statements of Dr. Stevens.

Berzelius finds the colouring particles only concerned in these changes. Prevost and Dumas found more fibrin and red particles in arterial than in venous blood; and the venous must contain a larger quantity of carbonic acid, and the arterial an abundance of oxygen: Macaire and Marcet, on *ultimate* analysis, find about five per cent more oxygen in arterial, and five per cent more carbon in venous, blood.[d]

It is in the red covering of the particles, or hematosine, as the colouring matter is now called, that the iron of the blood exists. Berzelius informs us that serum, although able to dissolve a small portion of the oxides, not indeed of the phosphates, of iron, does not acquire a red colour by their addition, and that he has never discovered iron nor lime in the entire blood, although both are so abundant in its ashes. He concludes that

[c] Boyle, *Ph. Tr.* 1666–7. Haller, *El. Phys.* lib. v. 1757. Hewson, *Ph. Tr.* 1770. Dr. Priestley, *Ph. Tr.* 1776. He adds that the urine makes blood florid because of its saline nature. Dr. Stevens, more minutely, l. c. 1832.

[d] *Mém. de la Soc. Phys. et d'Hist. Nat. de Genève,* t. v. p. 400.

the blood contains the *elements* of phosphate of iron and of lime, and of carbonate of lime, and also of phosphate of magnesia, united in a manner different from their combination in the salts. M. Raspail, seven years ago, showed that certain coagulable substances will protect a metal from the strongest re-agent — that a mixture of oil and the salts of iron will afford no signs of the metal till some days after it has been placed in acidulated ferro-chyazate of potass. Rose obtained the same result on mixing albumen or gelatine with peroxide of iron. But Dr. Engelhart has shown iron to exist in blood, by the usual liquid tests, after passing a stream of chlorine through a solution of red particles.[e]

"The last constituent principle of the blood to be noticed, is the plastic *lymph*, formerly confounded with the serum. This has been called the basis of the crassamentum, the glutinous part, the fibre or fibrous matter of the blood." It is now termed *fibrin.*

"It is properly denominated plastic, because it affords the chief materials from which the similar parts, especially the muscles, are immediately produced; nourishes the body throughout life; repairs wounds and fractures in an extraordinary manner; fills up the areæ of large blood-vessels when divided[f]; and forms those concretions which accompany inflammations[g], and that remarkable deciduous membrane found in the recently impregnated uterus for the attachment of the ovum."

We will now consider the coagulation of the fibrin more minutely.

Blood coagulates when it has escaped from the body, whether warm or cold, in the air or in vacuo, diluted within certain limits or undiluted, at rest or in motion. Within the vessels, rest, which causes a cessation of intercourse between the motionless portion and the general mass, always disposes it to coagulate. Yet its

[e] *Edinburgh Medical and Surgical Journal*, Jan. 1827. Engelhart's Essay obtained the prize at Göttingen in 1825.

[f] "T. F. D. Jones, *On the process employed by nature in suppressing the hemorrhage from divided* &c.^m *arteries*. London. 1805. 8vo. Translated into German, and supplied with notes by G. Spangenberg. Hanov. 1813. 8vo."

[g] "Such are those *spurious membranes* found exuded on the surface of inflamed viscera, *v. c.* those cellular connections between the lungs and pleura after peripneumony, and the tubes observed within the bronchia after croup; such also are those artificial ones, called, from their inventor, Ruyschian, and made by stirring fresh blood about with a stick." Although they are fibrinous, they contain a fluid in their cells that is albuminous.

coagulation, after escape from the body, is said to be accelerated by motion, a high temperature, and a vessel calculated to preserve its temperature, by a vacuum, and by the stream from the blood-vessel being slow, and *vice versâ:* in short, by every circumstance which favours the escape of carbonic acid gas, and to be proportioned to the quantity of carbonic acid gas evolved; this being evolved during the coagulation, and ceasing to escape when the coagulation is complete.[h] Galvanism and oxygen gas raise its temperature and hasten coagulation, while carbonic acid gas, azote, and hydrogen, have the opposite effects. Dilute mineral acids coagulate the blood: alcalies and their carbonates retain it fluid.

The coagulation of the blood is ascribed by J. Hunter to its life[i]; by Mr. Thackrah[k], on the contrary, to its death, as the separation of a portion from the mass, by escape from a vessel, is likely to kill it if alive; as every change likely to impair life promotes coagulation, for example, debility, fainting; and as blood frozen, and therefore likely to be killed if alive, and again thawed, instantly coagulates. But the coagulation appears, in most instances, if Sir C. Scudamore's experiments be accurate, though others have not found the same results[l], attributable merely to the escape of carbonic acid; and as coagulated blood or fibrin (and the coagulated part of effused blood is fibrin) becomes vascular, one can hardly, if the fluid is alive, regard a coagulum as necessarily dead.

Large quantities of blood are found fluid in every dead body, showing that simple loss of vitality is not sufficient to cause coagulation. Indeed, the blood of the various parts of the heart and vessels is found, most frequently, in opposite states, fluid in one part, coagulated in another; yet it is all equally dead. From all these contradictory circumstances, I regard the coagulation of the blood as quite unconnected with its vitality or lifelessness, and as entirely a chemical result. That it, however, is influenced by the vital properties of the containing vessels is possible, but these may operate upon the blood, in this respect, as a mere chemical compound; and even, if it be alive, and they influence its life, still the influence, as far as respects coagulation, may in effect be chemical.

[h] Scudamore, l. c.

[i] *A Treatise on the Blood*, &c.

[k] *An Enquiry into the Nature and Property of Blood.* By C. Turner Thackrah. London, 1819.

[l] Dr. Turner, *Elements of Chemistry*, 1827. p. 638.

The blood generally coagulates in the living body on escaping from its vessels, and even in its vessels if its motion be prevented by ligatures; and when it does not, its subsequent escape from the body almost always produces instant coagulation.[m] It almost always coagulates also in the vessels running through healthy parts to others in a state of mortification, and in large vessels adjoining a pulmonary abscess; in which cases, the final cause or purpose — prevention of hæmorrhage, is evident. The efficient cause, however, in all these examples, is unknown. In all, the blood is still in contact with living parts: in the last two, it is perhaps not at rest till it coagulates. J. Hunter, after mentioning that in a mortification of the foot and leg he found the crural and iliac arteries completely filled with strongly coagulated blood, adds, that this could not have arisen from rest, because the same thing ought then to happen in amputation, or in any case where the larger vessels are tied up.[n] Besides, coagulation after extravasation, or when a quantity is included in a vessel between two ligatures, is not an invariable occurrence.

These facts, in addition to those stated above, show that fluidity or coagulation is not dependent on the simple presence or absence of vitality. Whatever connection coagulation out of the body may have with the escape of carbonic acid gas, there is no proof of it in the case of internal coagulation.

Some have imagined the globules to be not only endowed, through vitality, with spontaneous motion, but with repulsion, which ceases with life, and thus by their death to run together and produce the phenomenon of coagulation. But M. Raspail contends, as we have noticed, that such spontaneous motion is a microscopic accident, and that, so far from being organised, they are merely minute precipitations of albumen; and he shows that, when the blood coagulates, the globules are seen under the microscope enveloped in the coagulum, which, therefore, cannot be a mere union of them. He asserts, that fibrin and albumen are identical, and that the fibrin is preserved liquid by the alcalies of the blood, — soda and ammonia; which, if they become saturated by the carbonic acid of the atmosphere and that which forms in blood when exposed to the air, can no longer act as a solvent,

[m] J. Hunter mentions the coagulation of blood let out from the tunica vaginalis, in which it had lain fluid sixty-five days after a wound. *On the Blood*, p. 25.

[n] l. c. p. 23.

and the fibrin accordingly coagulates.[o] The escape of the ammonia and of a certain quantity of the water of the blood augments this effect, and blood coagulates the sooner in proportion as it is less watery. Coagulation within the blood-vessels he regards as produced by the escape of some of the water of the blood through the coats of the vessels. Some glutinous saps, as that of the *chara hispida* (stone-wort), coagulate, like the blood, chyle, and milk, and they all have albumen in the state of globular precipitation and solution, have the same salts, and their coagulation ceases when the solvent of the albumen is saturated, evaporated, or weakened. In sap, the solvent is acetic acid.[p]

The fibrin may be separated from the red particles by agitation, and in inflammatory diseases it very frequently separates when drawn. Some conceive, that in health the cruor has a greater affinity for fibrin than for the serum, and therefore unites with it in preference. But to suppose any affinity of the red particles for either the fibrin or the serum is erroneous. Leeuwenhoek and Hartsoeker long since proved that serum merely suspends them; for if, when separated, they are triturated in some serum, part of them is taken up and the serum assumes a red colour; but, if the fluid is allowed to settle in a cylindrical glass, they slowly precipitate themselves to the bottom, and the serum above becomes clear as before. When blood is drawn, the serum easily separates on the coagulation of the fibrin. But the fibrin coagulates before the colouring particles have time to fall to the bottom, and entangling them acquires a red colour, forming the crassamentum: if, however, the fibrin coagulates slowly and is thinner[q], as in the phlogistic diathesis and pregnancy, the greater specific gravity of the cruor detaches it very considerably from the fibrin, which remains colourless above, constituting what is called the inflammatory coat, crust, or buff. Berzelius even believes the fibrin to be in a state of solution in the serum, while the cruor is simply suspended in this solution. In the phlogistic diathesis both the fibrin and the serum are more abundant, and the blood lighter.[r]

Thinness of the blood and a disposition to slow coagulation

[o] Dr. Prout also says, " A portion of soda is requisite to preserve the weak alcaline condition, essential to the fluidity of the blood." l. c. p. 496.

[p] l. c. p. 372. sqq.

[q] Hewson, *Experimental Enquiries into the Blood and the Lymphatic System*, P. 1. p. 45. sq.

[r] Scudamore, l. c.

generally co-exist. But the rapidity of the stream greatly affects the rate of coagulation, so that one portion of the same blood coagulates slowly that is drawn quickly, and another quickly that is drawn slowly.

The appearance of the buffy coat does not arise from the slow coagulation, though increased by it; because, of two portions of the same blood, one has afforded no buffy coat, although it remained fluid at least ten minutes after the buffy coat began to be formed on the other[s], proving, too, if the buffy coat arise from thinness of the fibrin, as appears from Mr. Hewson's experiments, the red particles continuing of their usual weight, that slow coagulation is not altogether dependent on mere thinness of the blood, though generally connected and proportional with it. Yet rapid coagulation, by means of a slow stream when the blood is thin, may prevent the buffy coat, by not allowing time for the difference in the weight of the fibrin and red particles to have effect. Stirring such blood, or receiving it into a shallow vessel, has the same consequence, and the slower the coagulation of thin blood, occasioned, for instance, by rapid bleeding, the greater will be the buffy coat.

If one portion of the same blood is received into a shallow, and another into a deep vessel, the coagulum of the former is looser and spongy, and the quantity of separated serum less.

The different cups of blood drawn in an inflammatory disease may vary as to the buffy coat, according to accidental variations in the stream; but generally it is the first cup that abounds in buff, and the last frequently has none. This occurs when there is no difference in the stream.[t] Therefore, if the buff arise from thinness of the fibrin, we must conclude with Hewson[u] that its qualities may be changed even during bleeding. Sir C. Scudamore finds much more fibrin in buffy blood; and, consequently, that not merely the thinness, as Hewson observed, but the quantity, of fibrin may vary during the flow of blood.[x]

The greater the strength of the patient and the intensity of the inflammation, the firmer is the coagulum of fibrin and the more cupped its appearance.

Sir C. Scudamore did not find a buffy coat in blood drawn immediately after violent exercise.

[s] Hewson, l. c. p. 90.
[t] l. c. p. 52. sqq.
[u] l. c. p. 56. sqq.
[x] l. c. p. 96.

Fibrin is inodorous and tasteless, whitish, insoluble in alcohol and acids, slightly soluble in boiling water long applied; coagulates, as already said, when separated from the body; dries hard, brittle, and semitransparent.

Albumen is inodorous, tasteless, colourless, soluble in water, and coagulates by a temperature of 150°, by pure potass, the mineral acids, tannin, and many metallic salts, especially by bichloride of mercury, and by prussiate of potass if a little dilute acid is previously mixed with it. Acetic and some other acids dissolve it, and even render it to a certain point soluble in alcohol and boiling water, according to M. Raspail; who also, under the microscope, discovers albumen to consist of two substances, the one an insoluble and organised tissue, the other a fluid contained in the cells of this.[y] The insoluble portion, however, forms gradually only, and in fresh eggs can scarcely be distinguished from the soluble; just as is the case with the woody fibres of vegetables, that gradually form from a gum. Dr. Wollaston stated, that the soda of albumen prevents it from all coagulating by heat, and the addition of an acid, by neutralizing the alcali, renders it completely coagulable.[z] Raspail says[a], "alcaline solutions, even alcaline carbonates," prevent heat from coagulating albumen. Mr. Brande thinks it liquid only through alcali.[b]

Chemists all allow that fibrin, albumen, and colouring matter afford, on decomposition, the same saline and gaseous products. Berzelius views them all three as modifications of the same substance. Albumen contains a greater proportion of oxygen than fibrin, and has sulphur for a constituent part, which, however, cannot be detected while the albumen is entire, any more than the iron while the cruor is entire. The chief differences between the colouring matter and fibrin are, colour; the spontaneous coagulation of fibrin at all temperatures, while the colouring matter may be dried without losing its solubility in water and becomes insoluble only at a certain temperature; and the peculiarity in the latter of not diminishing in volume like fibrin during exsiccation. According to most chemists, albumen is intermediate between the two; and its only character of distinction from fibrin is, that it does not coagulate spontaneously, but requires a high temperature or some chemical agent. M. Raspail maintains that albumen and fibrin are identical; and that the slight differences

[y] *Hewson*, l. c. p. 191. sqq.

[z] *Ph. Tr.* 1811.

[a] *Hewson*, l. c. p. 198.

[b] *Ph. Tr.* 1809.

between the two are referable to the natural and adventitious salts of albumen, varying according to the organs from which it is obtained. The following results are given[c] by Gay-Lussac and Thénard, in regard to them and gelatine:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Gelatine - - -	47·881	7·924	27·207	16·998
Albumen - - -	52·883	7·540	23·872	15·705
Fibrin - - -	53·360	7·021	12·685	19·934

Besides which, they, as well as the colouring matter of the blood, contain a very minute portion of the earthy phosphates.

We formerly saw that Dr. Prout is of opinion, at present, that when oxygen and hydrogen exist united, it is in the form of actual water, as an essential constituent of unazotised vegetable bodies, one atom of carbon being united with one of water. Now M. Raspail makes it highly probable, that the nitrogen of vegetable gluten, of albumen, fibrin, gelatine, and other animal matters, exists combined with another portion of hydrogen in the form of ammonia, which again is combined, as a base, with some acid, making an ammoniacal salt. The remaining small quantity of the hydrogen, not united with oxygen into water, is united with carbon into carburetted hydrogen; so that substances called azotised are really not azotised. He shows that the numbers given by Thénard are such as will give so much water, ammonia, and carburetted hydrogen, with pure carbon. Vegetable substances have been hitherto considered as ternary compounds of oxygen, hydrogen, and carbon: animal substances, and vegetable gluten, quaternary compounds of oxygen, hydrogen, carbon, and nitrogen; for most animal substances usually afford nitrogen, and but few vegetable substances excepting gluten. In M. Raspail's views, organised bodies consist of water, ammonia, carbon, and salts. And here I must remark, that the alcaline, earthy, and other substances, found in minute quantities in animal and vegetable compounds, and which have usually been regarded as foreign and unimportant, are, with great reason, considered by Dr. Prout as integrants in the compounds, and chiefly productive of the striking differences observed in substances having otherwise the same essential composition. The importance of minute quantities of matter is shown, he remarks, in the experiments of Sir John Herschel, who found that a power not less

[c] *Recherches Physico Chimiques*, t. ii.

than 50,000 times greater than the power of gravity, is constantly generated (under the galvanic influence, for example) by the alloy of mercury with a millionth part of its weight of sodium. Dr. Prout regards these incidental particles as in a state of mutual repulsion, because, instead of being equally diffused as they are, they would otherwise be collected into a mass or crystal.[d]

I may mention, that Dr. Prout says perhaps it may be stated as a general law, that no substance, entering into the composition of a living plant or animal, is so pure as to be capable of assuming a regularly crystallised form. Instead, therefore, of being defined by straight lines and angles, all solid organised substances are more or less rounded, and their intimate structure is any thing but crystallised. The composition of organised fluids is equally heterogeneous; and, though the basis of nearly every one of such fluids is water, many of them contain a variety of other matters.

M. Raspail remarks further, that the constituents of organic solids or fluids are not combined in definite proportions, like those of inanimate bodies, but are ever variable, so that the varieties of each compound are infinite.[e]

[d] *Bridgewater Treatise*, p. 425. sq.

[e] l. c. p. 78. sq.

"The idea of succession and developement leads to the conclusion, that, if the products are examined at a certain period, they will be found chemically more or less heterogeneous, and more or less mixed. In some, the combined water and carbon are not yet combined with a base, or at the utmost are mixed with one; then we have gum. In others, the carbon is mixed with hydrogen only, or at the utmost with a small quantity of water: that this may assume the characters of a substance fit for organisation, it must obtain sufficient oxygen aspired by the cellular apparatus, to transform all the hydrogen into water; till then the compound was an oil, or resin. Finally, the carbonic acid absorbed, instead of uniting with a quantity of hydrogen sufficient to convert the oxygen of the acid into water, may unite with a fresh quantity of water or other substances, even with a quantity of salts insufficient to neutralise them, and then, becoming an acid of a new form, it will serve as a brute unorganised body for the elaboration or the decomposition of the salts which are necessary for the developement of the tissues."

Most cold-blooded animals, as fishes and the amphibia, have a much smaller proportion of blood and fewer blood-vessels than those with warm blood, though a much greater number of colourless vessels arising from the arteries. In an experiment which Blumenbach made on this subject, he "obtained from twenty-four adult water-newts (lacerta palustris), which had been just caught, and weighed each an ounce and a half, ℈ iijss. of blood. The proportion to the weight of the body was as $2\frac{1}{2}$ to 36, while in healthy adult men it is as 1 to 5." (*Compar. Anatomy*, ch. xii. ed. i. p. 245. Translated by Mr. Lawrence.)

The blood of different brutes coagulates in different times. Mr. Thackrah imagines the rapidity to be inversely as the strength and size. Thus, while in health, human blood coagulates in from 3 or 4 to 7 minutes, that of the

Horse,	in from	2	to	15
Ox,		2	to	10
Dog,		½	to	3
Sheep, hog, rabbit		½	to	1½
Lamb,		½	to	1
Fowls,		½	to	1½

Mice, in a moment.
Fish, according to Hunter (l. c. p. 211.), also in a moment.

The blood of brutes has the same general character as our own, and Rouelle obtained the same ingredients, though in different proportions, from the blood of a great variety of them. Berzelius finds a larger proportion of nitrogen in that of the ox, and analogy would lead us to suppose there is a peculiarity in the blood of every species. Muscles look pretty much alike in various animals, yet when cooked they disclose the greatest diversities. Transfusion, or pouring the blood of one system into another, satisfies us, that the blood, whether arterial or venous, of one *individual*, agrees well enough with another of the same species; but some late experiments of Dr. Leacock (*Medico-Chirurgical Journal*, 1817, p. 276.), and subsequently of Dr. James Blundel (*Medico-Chirurgical Transactions*, 1818), render it unlikely, contrary to the opinion of former experimentalists, that the blood of one *species* suits the system of another. Dr. Young found the large outer globules of the skate to be somewhat almond-shaped, and Hewson found them of different shapes in different animals, and Rudolphi observed them to be more or less oval in the common fowl and many amphibia. (*Grundriss der Physiologie*, 159.) MM. Prevost and Dumas have noticed, in their microscopic experiments, a great difference in the blood of different animals as to the globules, and in this way explain the impossibility of transfusing the blood of some animals to others without danger to life. They assert that the quantity of the particles is proportionate to the temperature of the animal, and that, consequently, most exist in the blood of birds: that the size and shape also vary, although the size of the central portion is the same in animals in which they are spherical, and is about $\frac{1}{7500}$ of an inch in diameter: and that the shape of the external part is circular in the mammalia, and elliptical in birds (M. Raspail says, in oviparous quadrupeds also) and cold-blooded animals, thus confirming and generalising the observations of others, for Hewson observed the difference of their size in different animals, and that this bore no relation to the difference in the size of the animal (l. c. part iii. p. 10. sqq.): and they find the shape of the central portion correspondent with that of the external,—spherical when the latter is circular, oval when elliptical. They assert that, if the blood of two animals of different species, the blood of one of which was transfused into the other, differed in the size only of the globules, temporary restoration of energy took place; but that, if it differed in their shape, convulsions and death were the result. They also find a larger proportion of fibrin and red globules in warm than in cold blooded animals, and a larger in the former according to the height of the temperature — (of 10,000 parts by weight; in pigeons, 1557; man, 1292; frogs, 690); — a smaller, also, accordingly as animals are bled; it thus appearing that bleeding promotes the absorption of watery fluid. (*Annales de Chimie*, t. xviii. xxiii. 1821 and 1823.) The colour of the particles differs in different animals: hence red and white blooded animals.

Hewson (l. c. part iii. p. 39.) saw the red particles of the blood of the fœtal chicken and viper larger than those of the adult animal: and Prevost and Dumas have observed the red particles of the fœtal goat to be as large again as those of the adult; and those of the chicken to be circular, till about the sixth day, when some elliptic ones are first seen; and on the ninth, from their progressive multiplication, none but elliptic ones can be detected. (*Annales des Sciences Naturelles*, 1824, 1825.)

In the frog the particles are $\frac{1}{40}$, and in the salamander even $\frac{1}{30}$, of a millimètre, — the largest known.

The blood of invertebral animals is colourless, but has not been analysed.

The temperature of the blood, in general, varies with that of the animal.

The sap of vegetables is different, accordingly as it is examined when ascending from the roots, or descending again. The ascending sap is chiefly a watery solution of alcaline, earthy, and even metallic matters, and the proportion of water is very large, on account of the little solubility of many of these; the descending, or returning sap, is the same concentrated by exhalation from the leaves, and loaded with carbon, obtained in them from the atmosphere.

The former may be compared to chyle, the latter to blood; and this is more and more elaborated and converted into various organic substances, so as to be saccharine, fecular, glutinous or milky, oily, resinous, gum-resinous, and oleo-glutinous.

All vegetable principles are divided by Dr. Prout (*Bridgewater Treatise*, p. 454.) into three great classes—those in which oxygen and hydrogen are combined in the proportions which form water — the saccharine; those in which hydrogen, or rather carbon and hydrogen, predominate — the oily; and those in which oxygen predominates — the acid. Some contain azote also, like animal principles, from which, indeed, it is never absent; and some, weak alcaline powers, as quinine, morphine, &c.

About forty years after the discovery of the circulation of the blood, *transfusion* was practised upon brutes, and at length upon the human subject, though some contend that the operation was known to the ancients. Experiments were made upon the effects of injecting medicated liquids into the blood, first by Wahrendorf, in Germany. It was ascertained that they exert their specific powers exactly as when swallowed, — cathartics, *v. e.* purging, and emetics emptying the stomach. Among other liquids, Dr. Christopher Wren proposed that blood should be injected, and Dr. Lower first put this into practice. It was found that if an animal was drained of its blood, and lay faint and almost lifeless, and the blood of another was transfused into its circulating system, it soon revived, stood up, and presently ran about as before, apparently none the worse for the operation. If too much was poured in, the animal became drowsy, breathed with difficulty, and died of plethora. An idea of curing diseases in this way, by substituting the blood of the healthy for that of the diseased, was immediately entertained when the possibility of the operation was proved.

But the first case of human transfusion proved fatal, and the unfortunate results of some careless trials caused the Pope and the King of France to prohibit the practice.

The extravagant hopes of curing diseases and restoring youth, at first entertained in France, were disappointed, and the operation fell into complete neglect, notwithstanding that Denys, in France, was declared to have made a fool clever by a supply of lamb's blood; a Mr. Cox, in England, to have cured an old mongrel of the mange with the blood of a young spaniel; and a M. Gayant to have made a blind old dog frisk with juvenile bound, which before could hardly stir; till Dr. Leacock brought it again into notice a few years ago, and Dr. James Blundel prosecuted this gentleman's researches. Dr. James Blundel conceived it might be rationally expected to be of benefit in cases of dangerous hæmorrhage, and he soon proved it to be void of danger in the human subject, if properly performed. Many women, who would probably otherwise have perished from uterine hæmorrhage, now owe their lives to his disinterested zeal in establishing the practice.

I should think it applicable to many cases of exhaustion, besides those arising from hæmorrhage. The original history of transfusion will be found in the early numbers of the *Philosophical Transactions:* the successful cases of its employment as a remedy, in the late English journals. The double pump employed for emptying the stomach, or a common syringe, capable of holding four or six ounces, answers very well. But Dr. Blundel at present, when he has able assistants, sometimes receives the blood from the blood-vessel into a funnel, the tube of which is very long, and inserted in the vein of the subject supplied, so that the blood enters by its gravity only.

Very lately salts of potass and soda, dissolved in various quantities of water, have been injected into the veins of persons exhausted by the Asiatic epidemic, improperly called Cholera. The effect is often astonishing. The patient, apparently almost lifeless, often revives, sits up, speaks, and takes nourishment. The improvement is transient, but frequently recurs on repeating the injection, and sometimes life has probably been saved by the measure. Many pints of saline fluid have thus sometimes been introduced in a few hours. Occasionally, oppression of the head has been induced; but generally a greatly increased discharge of fluid from the alimentary canal occurred.

CHAP. XI.

THE MOTION OF THE BLOOD.

"THE blood, to whose great and multifarious importance in the system we have slightly alluded, is conveyed, with a few exceptions, into the most internal and extreme recesses. This is proved by the minute injection of the vessels, and by the well-known fact of blood issuing from almost every part on the smallest scratch.

"This red fluid does not, like an Euripus, ebb and flow in the same vessels, as the ancients imagined, but pursues a circular course; so that, being propelled from the heart into the arteries, it is distributed throughout the body, and returns again to the heart through the veins.[a]

"We shall, therefore, say something at present of the *vessels* which contain the blood, and afterwards of the *powers* by which they propel and receive it.

"The vessels which receive the blood from the heart, and distribute it throughout the body, are termed *arteries*.

"These are, upon the whole, less capacious than the veins; but in adult, and advanced age especially, of a texture far more solid and compact, very elastic and strong.

"The arteries consist of three *coats*[b]:—

"I. The exterior, called, by Haller, the TUNICA CELLULOSA PROPRIA; by others, the nervous, cartilaginous, tendinous, &c. It is composed of condensed cellular membrane, externally more lax, internally more and more compact: blood-vessels are seen

[a] "Among warm-blooded animals, the egg, especially at the fourth and fifth day of incubation, if placed under a simple microscope, such as the Lyonetian, is most adapted for the demonstration of the circulation.

Among frogs, the most proper is the equuleus of Lieberkühn, described in the *Mém. de l'Acad. de Berlin*, 1745."

[b] "For the various opinions respecting the number and differences of the arterial coats, consult, among others, Vinc. Malacarne, *Della Osservat. in Chirurgia.* Turin. t. ii. p. 103.

And C. Mondini, *Opuscoli scientifici*, t. i. Bologna, 1817. 4to. p. 161."

creeping upon it[c]; it gives very great tone and elasticity to the arteries.

"II. The middle coat consists of transverse fibres[d], lunated or falciform, and *almost* of a fleshy nature: hence this has the name of muscular coat, and appears to be the chief seat of the vital powers of the arteries.

"III. The inner coat lining the cavity of the arteries is highly polished and smooth," and is called the serous coat. It is brittle, so as to be cracked by a blow, a ligature fixed around the whole artery, or torsion of the vessel, while the external coat remains entire. The middle coat may give way at the same time, but frequently lacerates, through the pressure of the blood, by degrees only; and the external coat will remain entire, merely dilated into a pouch, for a length of time, — a state called false aneurysm. Dr. Hales found the carotid of a dog burst at once by the pressure of a column of water less than 190 feet high.[e]

"This is much more distinct in the trunks and larger branches than in the smaller vessels.

"Every artery *originates*, either

"From the pulmonary artery (the vena arteriosa of the ancients), which proceeds from the anterior ventricle of the heart, and goes to the lungs;

"Or from the aorta, which proceeds from the posterior ventricle, and is distributed throughout the rest of the system.

"These trunks divide into branches, and these again into twigs, &c.

"According to the commonly received opinion, the united capacity of the *branches*, in any part of the sanguiferous system, is greater than that of the trunk from which they arise. But I fear that this is too general an assertion, and even that the measure of the diameter has been sometimes improperly confounded with that of the area. I myself have never been able to verify it, although my experiments have been frequently repeated, and made, not on vessels injected with wax, after the

[c] "Fr. Ruysch, *Respons. ad ep. problematicam.* iii. Also his *Thesaur. Anat.* iv. tab. 3."

[d] "B. S. Albinus, *Annot. Academ.* l. iv. tab. 5. fig. 1."

[e] *Hæmastatics.*

bad example of some illustrious physiologists, but on the undisturbed vessels of recent subjects, *v. c.* on the innominata and its two branches—the right carotid and subclavian, on the brachial and its two branches—the radial and ulnar.[f]

"The inconstancy of the proportion between the capacity of the branches and that of the trunks is clearly shown by the various sizes of the vessels under different circumstances, *v. c.* by the relative capacity of the inferior thyreoid artery in the infant and the adult; of the epigastric artery in the virgin and the mother near her delivery; and also of the uterine vessels in the virgin and the pregnant woman; of the omental vessels during the repletion and vacuity of the stomach.[g]

"The arteries, after innumerable divisions and important anastomoses[h] connecting different neighbouring branches, *terminate* at length in the beginning of the veins. By this means the blood is conveyed back again to the heart. The distinction between artery and vein, at the point of union, is lost."

Some arteries terminate in cells; for instance, many of the penis and spleen.

"Another description of vessels arise universally from the arteries, and are called *colourless*, from not containing pure blood, either on account of their minuteness, or of their specific irritability, which causes them to reject that fluid."

"The blood conveyed from the heart throughout the body by the arteries is carried back by the *veins*.[i]

"These are very different in function and structure from the arteries, excepting, however, the minutest of both systems, which are indistinguishable.

"The veins, except the pulmonary, are universally more capacious than the arteries; more ramified; much more irregu-

[f] "See also J. Theod. Van Der Kemp, *De Vita*. Edin. 1782. 8vo. p. 51. And Seerp Brouwer, *Quæstiones Medic. varii argum.* Lugd. Batav. 1816. 4to. p. 8."

[g] "This is remarkably observable in the adult stag, by comparing the areæ of the external carotid and its branches, during the spring, just before the horns have attained their full growth, and when they are still covered with their downy teguments (called in German, *der Bast*), with such as they are after this covering has fallen off."

[h] "Ant. Scarpa, *Sull' Aneurisma*, Pav. 1804. fol. cap. 4."

[i] "H. Marx, *diatr. præmio ornata, de structura atque vita venarum.* Carlsr. 1819. 8vo."

lar in their course and division; in adult age, softer and far less elastic, but still very firm and remarkably expansile.

"Their *coats* are so much thinner that the blood appears through them. They are likewise less in number, being solely a cellular external, somewhat resembling the nervous of the arteries; and a very polished internal, also nearly agreeing with that of the arteries.

"A muscular coat exists only in the trunks nearest the heart.

"The interior coat forms, in nearly all veins of more than a line in diameter, very beautiful valves of easy play, resembling bags, generally single, frequently double, and sometimes triple, placed with their fundus towards the origin of the vein, and their edge towards the heart.

"These valves are not found in some parts: not in the brain, heart, lungs, secundines, nor in the system of the vena portæ.

"The twigs, or, more properly, the radicles, of the veins, unite into branches, and these again into six principal trunks: viz.—

"Into the two cavæ, superior and inferior;

"And the four trunks of the pulmonary vein (the arteria venosa of the ancients).

"The vena portæ is peculiar in this, that, having entered the liver, it ramifies like an artery, and its extreme twigs pass into the radicles of the inferior cava, thus coalescing into a trunk.

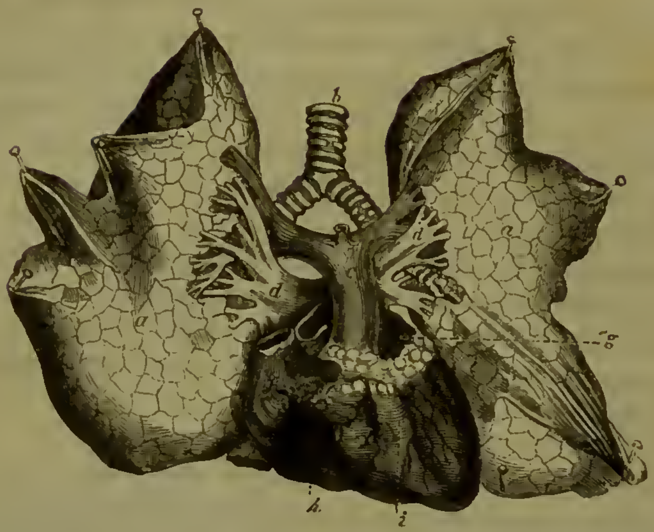
"That the blood may be properly distributed and circulated through the arteries and veins, nature has provided the *heart* [k], in which the main trunks of all the blood-vessels unite, and which is the grand agent and mover of the whole human machine,—supporting this—the chief of the vital functions, with a constant and truly wonderful power, from the second or third week after conception to the last moment of existence."

The heart is essentially a muscular organ, conical, with four cavities, placed in the left half of the chest, not quite vertically, but rather obliquely to the left, and from behind forward. Its size is usually about that of the closed fist of the individual.

"It is loosely contained in the *pericardium* [l], which is a membranous sac," consisting of two layers: the one fibrous and of the

[k] "W. Cowper, *Myotomia Reformata.* (Posth.) Lond. 1724. fol. max. Tab. xxxvi—xl."

[l] "Haller, *Elementa Physiol.* t. i. tab. i.
Nicholls, *Philos. Trans.* vol. lii. P. i. p. 272."



a, lungs.
b, trachea.
c, pulmonary artery.
d, pulmonary veins.
e, aorta.
f, right auricle.
g, left auricle.
h, right ventricle.
i, left ventricle.

same nature as the dura mater, though thinner; the other a true serous membrane, lining the inside of this, closely enveloping the substance of the heart, and "very firm, accommodated to the figure of the heart, and moistened internally by an exhalation."

It lies between the two pleuræ, and behind the anterior, and before the posterior, mediastinum. "Its importance is evinced by its existence being, in red-blooded animals, as general as that of the heart; and by our having but two instances on record of its absence in the human subject. [m]

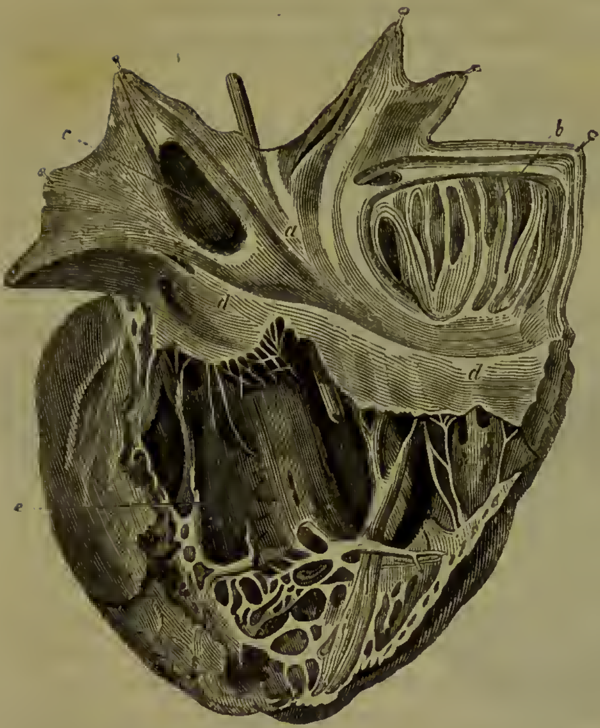
"The heart alternately receives and propels the blood. Receiving it from the whole body by means of the superior and inferior vena cava, and from its own substance through the common orifice of the coronary veins, that is supplied with a peculiar valve [n], it conveys that fluid into the anterior sinus and auricle, and thence into the corresponding ventricle, which, as well as the auricle, communicates with both orders of the heart's own vessels by the openings of Thebesius. [o]

[m] "Consult, *v. c.* Littre, *Hist de l'Académie des Sc. de Paris.* 1712. p. 37. Baillie, *Transactions of a Society for the Improvement of Medical and Chirurgical Knowledge*, t. i. p. 91."

[n] "Casp. Fr. Wolff on the origin of the large coronary vein, *Act. Acad. Scient. Petropol.* 1777. P. i.

Petr. Tabarrani on the same subject, *Atti di Siena*, vol. vi."

[o] "Respecting these openings, consult, among others, J. Abernethy, *Philos. Trans.* 1798. p. 103."

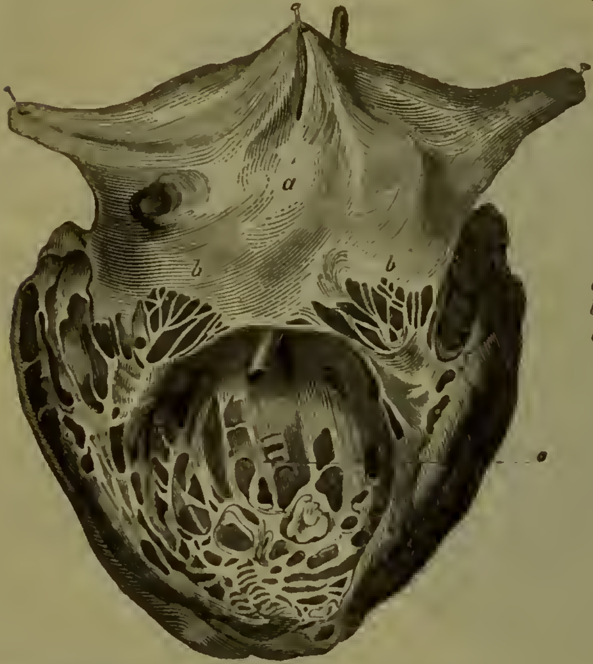


a, sinus of right auricle.
b, appendix of right auricle.
c, original seat of the foramen ovale.
d, tricuspid valve.
e, right ventricle.

"From this anterior, or, in reference to the heart of some animals, right, ventricle, the blood is impelled through the pulmonary artery into the lungs: returning from which, it enters the

a, right ventricle.
b, semilunar valves of pulmonary artery.
c, pulmonary artery: the aperture is the commencement of its right branch.

four pulmonary veins, and proceeds into their common sinus and the left, or, as it is now more properly termed, posterior, auricle. [p]



a, left auricle.
b, mitral valve.
c, left ventricle: a probe is passed through its opening into the aorta.

"The blood flows next into the corresponding ventricle; and

a, left ventricle.
b, semilunar valves of aorta.
c, aorta.

[p] "James Penada, *Memorie della Società Italiana*, t. xi. p. 555."

then, passing into the aorta, is distributed through the arterial system of the body in general and the coronary vessels of the heart itself.[q]

"Having proceeded from the extreme twigs of the general arterial system into the radicles of the veins, and from the coronary arteries into the coronary veins, it finally is poured into the two venæ cavæ, and then again pursues the same circular course.

"The regularity of this circular and the successive motion through the cavities of the heart is secured, and any retrograde motion prevented, by *valves*, which are placed at the principal openings, *viz.* at the openings of the auricles into the ventricles, and of the ventricles into the pulmonary artery and aorta."

"Thus the ring, or venous tendon, which forms the limit of the anterior auricle and ventricle, descending into the latter cavity, becomes these tendinous valves.[r] These were formerly said to have three apices, and were, therefore, called triglochine or *tricuspid:* they adhere to the fleshy pillars, or, in common language, the papillary muscles.

"In a similar manner, the limits of the posterior auricle and ventricle are defined by a ring of the same kind, forming two valves, which, from their form, have obtained the appellation of *mitral*."[s]

They are duplicatures of the lining membrane, with the addition of intervening fibrous membrane.

"At the opening of the pulmonary artery[t] and aorta[u] are found the triple *semilunar* or sigmoid valves[x], fleshy and elegant, but of less circumference than the mitral."

These are merely duplicatures of the lining membrane.

"It is obvious how these differently formed valves must prevent the retrocession of the blood into the cavities which it has left. They readily permit the blood to pass on, but are expanded,

[q] "Consult Achil. Mieg, *Specimen ii. Observationum Botanicarum*, &c. Basil, 1776. 4to. p. 12. sq."

[r] "Eustachius, tab. viii. fig. 6.—tab. xvi. fig. 3.—Santorini. Tab. Posth. ix. fig. 1."

[s] "Eustachius, tab. xvi. fig. 6."

[t] "Eustachius, tab. xvi. fig. 4."

[u] "Eustachius, tab. xvi. fig. 5.—Morgagni, *Adversar. Anat.* i. tab. iv. fig. 3. Santorini, l. c."

[x] "Consult Hunter, who treats very minutely of the mechanism of these valves in his work *On the Blood*, p. 159."

like a sail, against it, by any attempt at retrograde movement, and thus close the openings." The mere attempt at retrocession by the blood closes the semilunar valves: but the contraction of the muscular bands attached by tendons to the edges of the tricuspid and mitral valves during the systole of the ventricles will assist in closing the auriculo-ventricular openings.

"The *texture* of the heart is peculiar: fleshy, indeed, but very dense and compact, far different from common muscularity.[y]

"It is composed of fasciculi of fibres, more or less oblique, here and there singularly branching out, variously and curiously contorted and vorticose in their direction, lying upon each other in strata, closely interwoven between the cavities, and bound by four cartilaginous bands at the basis of the ventricles, which thus are, as it were, supported, and are distinguished from the fibres of the auricles."[z]

The heart was shown by Dr. Alexander Stewart[a], about the beginning of the last century, to be resolvable by boiling water into a semicircular muscle, with all its fibres running parallel to the base. Being rolled round in a funnel form, the left ventricle is produced with the apex, which thus belongs entirely to it; and the second turn produces the right ventricle, by the space between it and the first layer. The walls of the left ventricle, except the septum, are strengthened by another turn, which the right ventricle has not; so that the left ventricle is thicker than the right. The auricles are distinct, and by boiling drop off from the ventricles. They are very thin.

The interior of the heart is lined by the same membrane which forms the inner coat of the arteries and veins, being firmer and more opake in the left or arterial cavities, which are continuous with the arteries, than in the right or venous cavities, which are continuous with the venæ cavæ.

M. Gerdy has arranged the fibres of the ventricles into three orders — the one running from the heart's apex towards its base, and ending in tendons which are attached to the tricuspid

[y] "Leop. M.A. Caldani, *Memorie lette nell' Acad. di Padova.* 1814. 4to. p. 67."

[z] "Casp. Fr. Wolff, *Act. Acad. Scientiar. Petropol.* for the year 1780. sq., especially for 1781. P. i. p. 211. sq., on the cartilaginous structure of the heart, or on the cartilagineo-osseous bands, and their distribution at the base of the heart."

[a] *Phil. Trans.* vol. ix. abridg.

and mitral valves; the second detached in their centre, and fixed in the substance of the heart by their two extremities only; and the third fixed altogether in the substance of the organ.[b]

"The fleshy fibres are supplied with very delicate nerves[c], and an immense number of blood-vessels, which arise from the coronary arteries, and are so infinitely ramified[d], that Ruysch described the whole structure of the heart as composed of them."[e]

"By this structure the heart is adapted for its perpetual and equable motions, which are an alternate systole and diastole, or contraction and relaxation, of the auricles and ventricles in succession.

"The systole of the ventricles is performed in such a way that their external portions are drawn towards their septum, and the apex of the heart towards the base.[f] This at first sight seems disproved by the circumstance of the apex striking against the left nipple, and, consequently, appearing elongated, — a circumstance, however, to be attributed to the double impetus of the blood flowing into the auricles and expelled from the ventricles, by which double impetus the heart must be driven against that part of the ribs."

Dr. W. Hunter accounted for it thus in 1746: —

"The systole and diastole of the heart, simply, could not produce such an effect; nor could it have been produced, if it had thrown the blood into a straight tube, in the direction of the axis of the left ventricle, as is the case with fish, and some other classes of animals: but by throwing the blood into a curved tube, viz. the aorta, that artery, at its curve, endeavours to throw itself into a straight line, to increase its capacity; but the aorta being the fixed point against the back, and the heart in some degree loose and pendulous, the influence of its own action is thrown upon itself, and it is tilted forwards against the inside of the chest."[g]

[b] *Manuel d'Anatomie descriptive.* Par Jules Cloquet. Paris, 1825.

[c] "Scarpa, *Tabulæ Neurologicæ ad illust. Hist. Anat. cardiac. nervor.* tab. iii. iv. v.. vi."

[d] "Ruysch, *Thesaur. Anat.* iv. tab. iii. fig. 1, 2."

[e] "Brandis has proposed an ingenious hypothesis to explain the use of so great an apparatus of coronary vessels. *Versuch über die Lebenskraft*, p. 84."

[f] "Consult Ant. Portal, *Mémoires sur la Nature & le Traitement de plusieurs Maladies*, t. ii. 1800. p. 281."

[g] *Treatise on the Blood*, &c., by John Hunter, p. 146. Note.

Dr. Barclay has the following passage on this point: —

Though this is generally allowed, Haller remarks that in the frog also, which has a straight aorta, the apex of the heart moves forwards during the contraction[h]; and, in opposition to Blumenbach's explanation, some say that while the heart of a dog, rabbit, &c., continues to palpitate, after being extracted from the chest, the apex is lifted up at each contraction of the empty ventricles.[i]

The occurrence is ascribable likewise, in some measure, to the distension of the auricles; for Haller found the apex give the usual stroke at the nipple, on his distending the left auricle with air[k], and Senac[l] has shown a similar influence from the right auricle also. When the ventricles are contracting, no blood can leave the auricles, which must, therefore, become distended by its accumulation.

It is equally evident, that, when the ventricles dilate again, the blood must rush into them from the auricles.

These considerations show, without experiment, that the auricles and ventricles are always in opposite states, —that, when the ventricles are in systole, the auricles are in diastole, and *vice versâ*.

On applying the ear or a stethoscope to the region of the heart, two successive sounds may be distinctly perceived. At the moment of the stroke of the heart against the ribs (which stroke may be felt more strongly if the person lies on the left side), and

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"When the blood is forced into the arteries, their curvatures, near where they issue from the ventricles, are from their distension lengthened and extended towards straight lines; and, causing the heart to participate in their motions, compel it to describe the segment of a circle, when the apex moving atlantad and sinistrad, is made to strike against the left side. The same kind of motion having also been observed by the celebrated Haller, in distending the left or systemic auricle, it must follow, that the stroke which is given to the side, may be the effect of two distinct causes, either acting separately, or in combination: but acting on a heart obliquely situated, as ours is, in the cavity of the thorax, where the aspect of the base is atlantad and dextrad, and that of the apex sinistrad and sacrad. In combination, as the first of the two, by removing the pressure, will facilitate the influx of the venous blood into the left or systemic auricle, which is situated dorsad; so the second, by the influx of blood into the auricle, will contribute in its turn to facilitate the circular motion of the heart, proceeding from the arteries." *The Muscular Motions of the Human Body*, p. 567.

[h] *El. Physiol.* t. i. p. 394.

[i] Professor Mayo, *Outlines of Human Physiology*. 1827. p. 68. Dr. Hope, &c.

[k] l. c. ibid. where he refers to Senac and Ferrein.

[l] *Traité du Cœur*, p. 357.

at the moment of the pulse of the arteries, at least of those nearest the heart, is heard a dull sound; and immediately afterwards, without any interval, a clearer sound, similar to the noise of a valve or to the licking of a dog. The first sound occupies about $\frac{2}{4}$ of the whole time; the second sound $\frac{1}{4}$ or $\frac{1}{3}$, and then a pause occurs of about another $\frac{1}{4}$. This is termed the *rhythm* of the heart's action.[m] The *sounds* of the heart are ordinarily heard in health between the cartilages of the fourth and seventh left ribs, and under the inferior part of the sternum; those of the left side of the heart in the former situation, and those of the right in the latter. The first sound is usually loudest at the lower part of the heart's region; the second, at the higher part, in the situation of the auricles.

Whatever may be the cause of these sounds, the first occurs at the moment the ventricles contract: for it occurs at the instant the aorta receives blood from the left ventricle; and we know that both ventricles contract simultaneously. We might presume that the second sound occurs at the moment the auricles contract, and that therefore the auricles part with their blood immediately after the action of the ventricles. Again, when we reflect that the moment the ventricles have contracted, they relax, as is proved by our feeling and seeing the walls of the chest instantly recover their position after being forced outwards by the stroke of the heart, and as their relaxation is the production of a cavity for the blood of the auricles, we may hence be certain that the auricles discharge their blood into the ventricles instantly after the ventricles have discharged theirs.

In truth, those who open living animals assert that they see the apex of the heart recede from the walls of the chest, and the ventricles expand, instantaneously after their contraction, and that, at this moment of expansion, the blood rushes into them from the auricles, and a retractile motion of the auricles occurs most observable at the sinus.[n] It requires no vivisection to show that this must be the case.

[m] See the lamented Dr. Laennec's immortal work, *Traité de l'Auscultation Médiate, et des Maladies des Poumons et du Cœur*. (Edit. 1. 1819.) Edit. 3.

The force and extent of the sounds and shock, and the rhythm of the heart's action, are variously altered in disease, and other sounds superadded, resembling that of a bellows, a file, a saw, a drum, a dove, &c., all highly interesting to a philosophic mind, and indispensable to be known to all practitioners but empirics.

[n] Dr. Hope's *Treatise on the Diseases of the Heart and Great Vessels*. London, 1832. p. 40.

Dr. Whytt, and all old writers, declare, that, on opening living animals, they saw the auricles (that is, the appendix of the auricles) contract the first; and this is the modern experience of many. I have seen this in an ass stupified with prussic acid, opened by the desire of Dr. Hope. But in the same ass I repeatedly saw the appendices of the auricles contract many times to one contraction of the ventricles, resembling the tongue in the act of lapping, and repeatedly saw them contract after the ventricles. Whytt, though in experimenting upon a frog he saw the contraction of the auricle regularly precede that of the ventricle, says that the auricle continued to beat long after the ventricle had ceased: in an experiment upon a rabbit by Dr. Stevens, presently to be mentioned, it contracted for nearly three hours, though the ventricle was almost motionless. Sir B. Brodie, in all his experiments on dogs, rabbits, &c. never saw "any regular systole of the auricles corresponding to, and alternating with, that of the ventricles, and often used to observe several slight contractions of the auricle, especially of the appendix of the auricle, for one of the ventricle."[o]

The contraction of the appendices of the auricles is allowed to be very slight[p], and can hardly have much share in the circulation. The sinuses are always charged with blood, as reservoirs, and the appendices are probably intended only to enlarge the space by yielding under congestion. The contraction of the appendices is perhaps partly to prevent the blood from coagulating in them, as it might do, from their being blind pouches, were it not continually expelled. The sinuses of the auricles must part with some of their blood whenever the ventricles expand; and this period, — the moment after the contraction of the ventricles, — is the period at which the systole of the auricles must occur.

When the ventricles are nearly filled, and still more when contracting, the blood must accumulate in the auricles, and the stoppage be felt even in the large veins; for which reason, just before, or rather at, the moment of the systole of the ventricles, we sometimes see the jugulars swell.[q] Some have adduced the swelling of the jugulars before the stroke of the heart, as a proof that the auricles contract before the ventricles; but I have always found

[o] Dr. Hope's work, p. 37. sq.

[p] Dr. Hope, l. c. p. 39.

[q] See my Lumleyan *Lectures on the recent Improvements in the Art of distinguishing the various Diseases of the Heart*, p. 16. folio, with copperplates. London, 1830.

it occur at the same moment with their stroke[r]; and the impossibility of passage into the ventricle explains the fact. Indeed, not only, according to my experience, does the swelling of the jugulars occur after the moment assigned by these writers to the contraction of the auricles, but, as, at the moment the auricles lose their blood, the ventricles are relaxed or expanding, there can be no reason for the blood moving at all backwards when the auricles contract.

The object of the appendix of each auricle usually contracting later than the sinus, that is, just before the ventricle, if it really does, is probably, by pouring its blood into the sinus which has just parted with much of its own to the ventricle, and by lessening the space for the blood streaming to the auricles from the veins, to bring the distension of the ventricle, which is already in diastole, to the highest pitch; or, if the expansion of the ventricle is spontaneous, to thus cause it to be supplied with blood in proportion to its expansion.

Many hypotheses have been invented to explain the two sounds; and the periods of the action of the auricles and ventricles relative to each other and to the arterial pulse been strangely misrepresented. But Laennec was right in asserting that the first sound occurs *when* the ventricles part with their blood, and the second *when* the auricles part with theirs; for the first occurs when the heart strikes against the ribs and the aorta receives a fresh quantity of blood from the heart, and the second, when the ventricles expand and the blood must rush from the auricles: the first is loudest in the ventricular region, the second in the auricular: and, when the appendices of the auricles were contracting with all sorts of irregularity, — with no relation to the contraction of the ventricles in the ass, I heard, by means of the stethoscope, the two usual sounds occur with the greatest regularity. We may therefore presume that the first arises from the rush of blood from the ventricles, and the second from the rush of blood from the sinuses of the auricles.

" The impulse imparted by the heart to the blood is communicated to the arteries, so that every systole of the heart is very clearly manifested in those arteries which can be explored by the fingers and exceed $\frac{1}{6}$ of an inch in the diameter of their

[r] I have at this time a patient whose external jugulars are enormously distended, and immediately above the clavicles, the most frequent spot, their pulsation may be seen and felt exactly synchronous with the radial pulse.

canal, and in those also whose pulsation can be otherwise discovered, as in the eye and ear. The effect upon the arteries has been called their diastole, and is perfectly correspondent and synchronous with the systole of the heart," in vessels not distant from it; but, in distant arteries, the pulse has long been observed sometimes a very little later than the systole of the heart.

If an artery of tolerable size is divided, the blood escapes in jerks; if of smaller dimensions, it flows continuously, but is projected further at the moment of the pulse; and if the artery is very small, it flows in an uniform stream.

"The quickness of the heart's pulsations during health varies indefinitely; chiefly from age, but also from other conditions which at all ages form the peculiar constitution of an individual, so that we can lay down no rule on this point. I may, however, be permitted to mention the varieties which I have generally found in our climate[s] at different ages, beginning with the new-born infant, in which, while placidly sleeping, it is about 140 in a minute.

Towards the end of the first year, about -	124
———————— second year - -	110
———————— third and fourth year -	96
When the first teeth begin to drop out -	86
At puberty about - - - -	80
At manhood about - - - -	75
About sixty - - - -	60

"In those more advanced, I have scarcely twice found it alike." Like many others, I have counted it distinctly before birth, by applying the stethoscope to one side of the mother's abdomen. My observations have been made near the end of pregnancy, and I have counted 128 pulsations in a minute, while the mother's pulse was but about 80.

"The pulse is, cæteris paribus, more frequent in women than in men, and in short than in tall persons. A more constant fact, however, is its greater slowness in the inhabitants of cold climates.[t]

"Its greater frequency after meals and the discharge of semen, during continued watchfulness, exercise, or mental excitement, is universally known."

[s] "My observations differ but little from those made by W. Heberden in England, *Med. Trans.* vol. ii. p. 21. sq."

[t] "J. H. Schönheyder, *De Resolutione et Impotentia motus Muscularis.* Hafn. 1768. p. 15. With which work compare the observations of F. Gabr. Sulzer, *Naturgesch. des Hamsters.* p. 169."

It is commonly believed that the pulse of every person is quicker in the evening than in the morning, and some have supposed an increase of quickness also at noon. Upon these suppositions Dr. Cullen builds his explanation of the noon and evening paroxysms of hectic fever[u], as others had theirs of the evening exacerbations of all fevers[v], regarding them as merely aggravations of natural exacerbations. The existence of the noon paroxysms is doubtful, and the evening one cannot be so explained, if Dr. R. Knox is correct[w], though he is opposed to Haller, &c. His observations make the pulse to be slower in the evening, and quicker in the morning.

Dr. Heberden saw a woman fifty years of age, who had always an intermitting pulse, yet an able anatomist could discover nothing unusual after death; and two persons whose pulse was always irregular in strength and frequency when they were well, and became quite regular when they were ill.[x]

" The heart rather than the arteries is to be regarded as the source of these varieties, which we have, therefore, detailed here.

" Its action continues in this manner till death, and then all its parts do not at once cease to act; but the right portion, for a short period, survives the left. [y]

" For, since the collapsed state of the lungs after the last expiration impedes the course of the blood from the right side, and the veins must be turgid with the blood just driven into them from the arteries, it cannot but happen that this blood, driving against the right auricle, must excite it to resistance for some time after the death of the left portion of the heart.

" This congestion on the right side of the heart, during the agony of death, affords an explanation of the small quantity of blood found in the large branches of the aorta.

[u] *Practice of Physic.*

[v] Haller, *El. Physiol.* t. ii. p. 263.

[w] *Edinburgh Medical and Surgical Journal.* 1815.

[x] *Transactions of the College of Physicians.* London. vol. ii. p. 31. Similar cases are mentioned by Shenkius, De Haen, Monro, Rasori, and Andral.

[y] " Stenonis, *Act. Hafniens.* t. ii. p. 142.

Sometimes, though rarely, it happens that the right portion of the heart, oppressed with too much blood, becomes, contrarily to what usually takes place, paralysed before the left. This I have more than once observed on opening living mammalia, particularly rabbits."

"Weiss[z], and after him Sabatier[a], ascribe to this cause likewise the comparatively larger size[b] of the right auricle and ventricle after death, especially in the adult subject.

"The motion of the blood is performed by these two orders of vessels in conjunction with the heart. Its celerity in health cannot be determined; for this varies not only in different persons, but in different parts of the same person.

"Generally, the blood moves more slowly in the veins than in the arteries, and in the small vessels than in the large trunks, although these differences have been overrated by physiologists.

"The mean velocity of the blood flowing into the aorta is usually estimated at eight inches for each pulsation, or about fifty feet in a minute.

"Some have affirmed that the globules of the cruor move more in the axes of the vessels, and with greater rapidity, than the other constituents of the blood. I know not whether this rests upon any satisfactory experiment, or upon an improper application of the laws of hydraulics; improper, because it is absurd to refer the motion of the blood through living canals to the mere mechanical laws of water moving in an hydraulic machine. I have never been able to observe this peculiarity of the globules.

"My persuasion is still more certain that the globules pass on with the other constituents of the blood, and are not rotated around their own axis;—that besides the *progressive*, there is no *intestine* motion in the blood, although indeed there can be no doubt that the elements of this fluid are occasionally divided,—where they are variously impelled, according to the different direction, division, and anastomoses of the vessels.

"The moving *powers* of the sanguiferous system are now to be examined: first, those of the heart, by far the greatest of all; afterwards, those which are only subsidiary, though indeed highly useful.

"That the powers of the heart cannot be accurately calculated is clear, upon reflecting that neither the volume of blood projected at each pulsation, nor the celerity nor distance of its

[z] "J. N. Weiss, *De Dextro Cordis Ventriculo* POST MORTEM *ampliori*. Altorf. 1767. 4to."

[a] "Ant. Chaum. Sabatier, *E. in vivis Animalibus Ventriculorum Cordis eadem Capacitas*. Paris, 1772. 4to."

[b] "Sam. Aurivilius, *De Vasorum Pulmonal. & Cavitat. Cordis inequali Amplitudine*. Gotting. 1750. 4to."

projection, much less the obstacles to the powers of the heart, can be accurately determined, &c.

"A rough calculation may be made by taking every probable conjecture together: *v. c.*, if the mean mass of the blood is considered as 10 pounds, or 120 ounces; the pulsations 75 in a minute, or 4500 in an hour; and the quantity of blood expelled from the left ventricle at each contraction, as 2 ounces; it follows that all the blood must pass through the heart 75 times every hour.

"The impetus of the blood passing from the heart may be conceived by the violence and altitude of the stream projected from a large wounded artery situated near it. I have seen the blood driven at first to the distance of above five feet from the carotid of an adult and robust man.[c]

"This wonderful, and, while life remains, constant, strength of the heart, is universally allowed to depend upon its *irritability*, in which it very far surpasses, especially as to duration[d], every other muscular part.[e]

"That the parietes of the cavities are excited to contraction by the stimulus of the blood, is proved by the experiment of Haller, who lengthened, at pleasure, the motion of either side of the heart, by affording it the stimulus of the blood for a longer period than the other."[f]

[c] "The experiments of Hales, in which the blood was received into very long glass tubes fixed to the arteries of living animals, and the length of its projection measured, are indeed beautiful, like every thing done by this philosopher, who was calculated by nature for such enquiries. But, if the force of the heart is to be estimated in this way, we must take into account the pressure of the column of blood contained in the tube and gravitating upon the left ventricle.

"The result of Hales's calculations was, that, the blood being projected from the human carotid to the height of seven feet and a half, and the surface of the left ventricle being fifteen square inches, a column of blood, weighing 51·5 lbs. was incumbent upon the ventricle, and overcome by its systole. *Statical Essays*, vol. ii. p. 40. London, 1733. 8vo."

[d] "Thus, to say nothing of the phenomena so frequently observed in the cold-blooded amphibia and fishes, I lately found the heart of the chick to beat for twelve hours, in an egg, on the fourth day of incubation."

[e] "Consult Fontana, who treats of this prerogative of the heart minutely in his *Ricerche sopra la Fisica animale*, and limits it too much. Haller answered him in the Literary Index of Gottingen."

[f] "See Haller on the motion of the heart from stimulus. *Comment. Soc. Scient. Gottingens.* tom. i.

G. E. Remus, *Experimenta circa circulat. sanguin. instituta.* Gotting. 175 4to. p. 14."

The heart, however, of frogs, for instance, contracts and relaxes alternately, for a length of time, when out of the body and destitute of blood.

Sir B. Brodie divided the great vessels in rabbits, and found the action of the heart "apparently unaltered, for at least two minutes after that viscus and the great blood-vessels were empty of blood."[g] But the quantity of blood greatly influences the action of the heart.

"Since a supply of nerves and blood is requisite to the action of the voluntary muscles, it has been enquired whether these, both or either, are requisite to the heart also.[h]

"The great influence of the *nerves* over the heart, is demonstrated by the size of the cardiac nerves, and by the great sympathy between the heart and most functions, however different. A convincing proof of this is, the momentary sympathy of the heart during the most perfect health[i] with all the passions, and with the *primæ viæ* in various disorders.

"The great importance of the blood to the irritability of the heart is evident from the great abundance of vessels in its muscular substance.

"Besides these powers of the heart, there is another which is mechanical, dependent on structure, and contributing greatly, in all probability, to sustain the circulation. For, when the blood is expelled from the contracted cavities, a vacuum takes place, into which, according to the common laws of *derivation*, the blood from the venous trunks must rush, being prevented, by means of the valves, from regurgitating."[k]

[g] Dr. Cooke, *A Treatise on Nervous Diseases*, vol. i. p. 63.

[h] "On this dispute consult *v. c.* R. Forsten, *Quæstion. select. Physiol.* Lugd. Bat. 1774. 4to.

J. B. J. Behrends, *Dissert. qua demonstratur Cor Nervis carere*, Mogunt. 1792. 4to.

And on the other side, J. Munniks, *Observationes variæ.* Groning. 1805. 4to. Lucæ, *Obs. circa Nervos Arterias adeuntes.* Francof. 1810. p. 37. tab. ii."

[i] "And how much more so when the heart is diseased, is shown *v. c.* in Caleb Hillier Parry's *Inquiry into the Symptoms and Causes of the* Syncope Anginosa, *commonly called* Angina Pectoris. Bath, 1799. p. 114."

[k] "Andr. Wilson, *Inquiry into the moving Powers employed in the Circulation of the Blood.* Lond. 1784. 8vo. p. 35. sq.

And at great length in J. Carson's *Inquiry into the Causes of the Motion of the Blood.* Ibid. 1815. 8vo." Second edition, 1833.

The influence of a vacuum, pointed out by Rudiger[l], enlarged upon by Dr. Andrew Wilson, and mentioned as probable by Haller[m], John Hunter[n], &c., has been very ably displayed by Dr. Carson of Liverpool.

The quantity of the blood, the length of its course, and the various obstacles opposed to its progress, render, in his opinion, the mere propulsive power of the heart insufficient to maintain the circulation perpetually. But assistance must be given by the vacuum which takes place in all the cavities of the organ, when the contraction of the muscular fibres is over. The blood is thus drawn into each relaxed cavity, and the heart performs the double office of a forcing and a suction pump. The situation of the valves of the heart is thus explained. There are valves at the mouths of the two great arteries, because behind each of these openings is a cavity of the heart, alternately dilating and affording a vacuum, into which, were there no valves, the blood would be drawn retrograde. There are valves between the auricles and ventricles, because the contraction of the ventricles tends to impel the blood back into the auricles, as well as into the pulmonary artery and aorta. At the venous openings of the auricles no valves exist, because they do not open from a part ever experiencing a vacuum and the blood does not appear to leave the sinuses of the auricles so much by their contraction, which would impel it in all directions, like the ventricles, as by the vacuum offered it in the dilated ventricle; and therefore the blood of the auricles will not move retrograde, but will necessarily pass forwards into the ventricles, which are offering a vacuum. The inferior elasticity and irritability of the veins are also explained. If veins were capable

[l] Quoted by Haller, *El. Physiol.* t. ii. lib. vi. p. 325.

[m] His words are — "Sanguinem in auriculam dextram, tanquam in *vacuum* castellum approperare, ne id quidem videtur absque specie veri dici." l. c. An idea of the same kind appears to have been entertained before the time of Rudiger, whose work, *De Regressu Sanguinis per Venas mechanico*, was published at Leipsig in 1704. For in Pecquet's *Experimenta nova Anatomica*, published in 1651, arguments are adduced against those who conceived that the diastole sucked the blood towards the heart, ("num, ut quibusdam placuit, ATTRAHENDO pelliciat EXUGATVE, investigandum." Chap. vii. sqq.) At that time suction was not generally known to be merely a means of removing or diminishing the resistance to the pressure of air, but supposed to be an occult principle. He details experiments to show its true nature, but urges nothing against suction in the proper acceptation of the term, and his adversaries were right in their fact, though ignorant of its true nature.

[n] *A Treatise on the Blood*, &c. p. 185.

of contracting equally with arteries, on the diminution of their contents, the suction influence of the heart would constantly reduce their cavities to a smaller capacity than is compatible with their functions. The collapse of the veins by pressure, during the suction of the heart, is prevented by the fresh supply of blood afforded by the vis a tergo, which does exist, although it is not considered by him as of itself adequate to convey the blood back to the right auricle.

All allow that when the heart is relaxed its cavities enlarge, though some ascribe this to its elasticity, and others regard it as a necessary consequence of the arrangement of its fibres. Experiment proves the same. Dr. Carson extracted the hearts of some frogs, and immediately put them into water, blood-warm. They were thrown into violent action, and, upon some occasions, projected a small stream of a bloody colour through the transparent fluid. The water could not have been projected unless previously imbibed. It was thought that a stream of the same kind continued to be projected at every succeeding contraction; but that, after the first or second, it ceased to be observable, in consequence of the liquid supposed to be imbibed and projected losing its bloody tinge and becoming transparent, or of the same colour with the fluid in which the heart was immersed. The organ was felt to expand forcibly during relaxation, — a fact stated long ago by Peclilin[o], and subsequently by many others. Indeed, some consider the expansion of the heart as a change equally active with its contraction: conceiving, perhaps, that different fibres may act alternately, and produce expansion and contraction, just as the tongue may be retracted and protruded, and the iris lessened or enlarged.

Dr. Carson accounts, however, for the full dilatation of the heart upon another principle, upon the consideration of which it will be impossible to enter before the next section, where the subject will therefore be prosecuted.

" We must now enquire what powers are exerted by other organs in assisting the circulation. The existence of some *secondary* powers, and their ability to assist, or even in some cases to compensate for, the action of the heart, are proved by several arguments: *v. c.* the blood moves, according to many persons," in some parts to which the influence of the heart cannot reach,

[o] *De Corde.*

— in the vena portæ and placenta; not to mention instances of the absence of the heart.[p]

"The principal of these powers is the function of the *arteries*, not easy indeed to be clearly understood and demonstrated. 1. It is well known, that they have a peculiar coat, which is all but muscular. 2. That they are irritable, has been proved by repeated experiments.[q] 3. The size of the soft nerves arising from the sympathetic, and surrounding the larger arterial branches with remarkable networks, particularly in the lower part of the abdomen[r], argues the importance of these vessels in assisting the motion of the blood.[s]

"All know that the arteries pulsate, and indeed violently, so that if, *v. c.* we place one leg over the other knee, we find not only that it, but even a much greater weight, may be raised by the pulsation of the popliteal. Hence an alternate systole and diastole, corresponding with those of the heart, have long been assigned to them.

"But this, although commonly believed on the evidence of sense, is open to much question[t]: it may be asked, especially, whether this pulsation is referable to the power of the artery, or only to the impulse given by the heart to the blood propelled into the aorta.

[p] "See *v. c.* C. W. Curtius, *De monstro humano cum infante gemello.* Lugd. Bat. 1762. 4to. p. 39.

W. Cooper, *Phil. Transact.* vol. lxv. p. 316.

And, instar omnium, Fr. Tiedemann, *Anatomie der Kopflosen Missgeburten.* Landshut, 1813. fol. p. 70. sq."

[q] "Walter Vershuir, *De arteriar. et venar. vi irritabili: ejusque in vasis excessu; et inde oriunda sanguinis directione abnormi.* Groning. 1766. 4to.

Rich. Dennison, *Diss. arterias omnes et venarum partem irritabilitate præditas esse.* Edinb. 1775. 8vo.

Chr. Kramp, *De vi vitali arteriarum.* Argent. 1785. 8vo."

[r] "Observe, for instance, in Walter's *Tabulæ nervor. thorac. et abdominis*, the right hepatic, tab. ii. O. tab. iii. *l.*—the splenic, tab. ii. P., tab. iii. *m.*, tab. iv. *o.*—the superior mesenteric, tab. ii. Q., tab. iii. *f.*—the inferior mesenteric, tab. ii. T.—and many others.

Consult Soemmerring, *De c. h. fabrica.* t. iv. p. 362."

[s] "Haller, *De Nervor. in arterias imperio.* Gotting. 1744. 4to.

Lucæ, l. c."

[t] "T. Kirkland, *Inquiry into the present state of Medical Surgery.* London, 1783. 8vo. vol. i. p. 306. sq.

But especially Cal. Hillier Parry's *Experimental Inquiry into the Arterial Pulse.* Lond. 1816. 8vo."

"And indeed, after all, it appears that the *diastole* of an artery is owing to a lateral distension given by the impetus of the blood, so that the coats are expanded, and, by their elasticity, the next moment reacquire their natural thickness. To the same impulse may be ascribed the lateral motion of the axis, observable in the larger arteries, if serpentine and lying in loose cellular substance.

"The genuine *systole*, produced by a contraction of their substance, scarcely occurs, probably, while the heart acts with vigour, but may, when they are unusually influenced by local stimulants; whence the pulse during illness is very different in different arteries of the same person at the same time; or when the action of the heart itself fails," &c.

Most physiologists grant to the capillaries irritability, tonicity, or organic contractility; but some deny that *arteries* possess muscular properties. Bichat's objections are, the absence of contraction on the application of stimuli to them, the much greater resistance of the middle coat to a distending force than of muscular parts, and, lastly, the difference of the changes which it and muscles undergo both spontaneously and by the action of other substances.[u] Berzelius has multiplied the latter description of proofs.[x] However this may be, I must remark, first, that the capillaries have certainly vital powers of contraction as fully as any parts of the body. This appears in their various degrees of *local* dilatation and contraction, under inflammation, passions of the mind, &c. When different stimuli are applied to them, they are seen under the microscope locally to experience various degrees of contraction and dilatation, and this even after connection with the heart has been cut off by absolute excision of this organ.[y] Under similar circumstances, when no stimulus was applied, the blood was seen by Dr. Hastings often to cease, indeed, to flow, but still to oscillate. If the capillaries are allowed to possess organic contractility, it is impossible to say in which point of the arterial tract it begins.

The evidence of muscular fibres is not necessary to irritability. The iris and uterus are strongly endowed with irritability, but their muscularity is disputed by many. No muscularity is dis-

[u] *Anatomie Générale*, t. ii.

[x] *Traité de Chimie*, t. vii. p. 84. sq.

[y] See Dr. Wilson Philip, *On Febrile Diseases;* Dr. Thomson, *Lectures on Inflammation;* Dr. Hastings, *A Treatise on the Inflammation of the Mucous Membrane of the Lungs.* 1820.

cernible in the plant called dionæa muscipula, nor in the sensitive plant, nor in those zoophytes which appear gelatinous masses; yet contractility dependent on life is very manifest in them.

Verschuir actually found the larger arteries contract on irritating them with a scalpel, in fifteen out of twenty experiments.[z] Dr. L. Bikker, and J. J. Vandembos assert the same of the aorta, and Van Geuns of the carotid when influenced by electricity.[a] Zimmerman, Bichat, and Magendie, saw the arteries contract upon the application of acids, but the two last considered it a chemical change. Dr. Hastings, however, saw the same from the application of ammonia. When a ligature was placed on the aorta of a frog by Dr. M. Hall, the circulation was almost instantly arrested, first in the capillaries, then in the veins, and the blood, during ten or fifteen minutes, would move on in the arteries for some seconds, and then all at once rapidly retrograde, and so alternately.[b] J. Hunter found the posterior tibial artery of a dog contract so as nearly to prevent any blood from passing through it on merely being laid bare, and facts similar to this are mentioned by Drs. Hastings, Fowler[c], Jones[d], and the Drs. Parry. Dr. Stevens destroyed a rabbit's brain with a bodkin, and opened the chest. The lungs collapsed, and the heart lay motionless. On opening the pericardium, a branch of the coronary arteries on the right ventricle began to contract, and acted forcibly till it had driven all its blood into the ventricle. It now was still, and the right auricle began to contract, and continued acting for two hours and three quarters, the ventricle being almost motionless.[e] Dr. Marshall Hall says, that the superficial muscles and heart of batrachian reptiles become rigidly contracted by water of 120°; and that, if an artery and vein be also plunged in it, the artery grows rigid like muscles, and cylindrical, while the vein suffers no apparent change.[f] The fact of continued contraction, and of alternate contraction and relaxation in arteries, being occasioned by stimuli, is therefore certain; and, although some have not succeeded in stimulating them, we must remember that others have

[z] *De Art. et Ven. vi Irrit.*

[a] See Hastings, l. c. The introduction to this work is a body of information on the present subject.

[b] *A Critical and Experimental Essay on the Circulation*, &c. by Marshall Hall, M.D. London, 1831. p. 78.

[c] *Disputatio inauguralis de Inflammatione.*

[d] *On Hæmorrhage.*

[e] l. c. p. 57.

[f] l. c. p. 78.

failed in the application of electricity to parts indisputably muscular; — Verschuir [g] in the case of the heart and urinary bladder, and Zimmerman in other parts of known muscularity. [h] Dr. Hastings caused contraction in veins also by the application of stimuli. [i]

Dr. Parry instituted a number of experiments upon this question. After exactly ascertaining the circumference of arteries in animals, he killed them, and again measured the circumference; and after a lapse of many hours, when life must have been perfectly extinguished, he measured the circumference a third time. Immediately after death, the circumference was found greatly diminished, and on the third examination it had increased again. The first contraction arose from the absence of the blood, which distended the vessels and antagonised its efforts to contract; and it was evidently muscular, or, to speak more correctly, organic, contraction, because, when vitality had ceased, and this kind of contraction could no longer exist, the vessel was, on the third examination, always found enlarged. [k]

The forced state of distension in arteries was proved by the contraction immediately occurring on making a puncture in a portion of vessel included between two ligatures. An experiment of Magendie's is of equal weight, in which a ligature was fixed on the whole of a dog's leg except the crural artery and vein, and the vein and artery were compressed, when, upon wounding the vein, the artery completely emptied itself. [l] The capacities of arteries are thus always accommodated to the quantity of blood, and this circumstance gives the arterial canal such properties of a rigid tube as enable an impulse at the mouth of the aorta to be instantly communicated throughout the canal. This appears the great office of the contractile powers of arteries, for,

[g] l. c. expt. 22. [h] *De irritabilitate.* [i] l. c. p. 52. sq.

Dr. M. Hall thought he found an artery, which branches off from the vessels that by their union form the aorta in the frog and toad, pulsate a considerable time after the removal of the heart, becoming straight and pale; whereas the pulmonary artery grows more tortuous and distended at the moment of the stroke of the heart. This, however, is no more a proof that arteries in other animals have muscular powers, than it is that other arteries in the same animal have muscular powers and exhibit the same phenomenon: and Dr. Müller (*Ph. Tr.* 1833) maintains that the vessel is a vein which beats only from the impulse of lymph sent into it through a lymphatic by a lymph-heart.

[k] See also J. Hunter, *On the Blood*, pp. 114. 116.

[l] *Journal de Physiologie*, t. i. p. 111.

They do not incessantly dilate and contract to any amount, as many imagine. They lengthen and become tortuous, so that John Hunter says, "instead of the term diastole it should rather be called the elongated state." [m] Dr. Parry, on the most careful examination, could never discover the least dilatation in them during the systole of the ventricle — when the pulse is felt. Dr. Hastings declares he has seen it, as does Magendie in the case of the aorta and carotid of the horse; but from the number and accuracy of Dr. Parry's experiments, I incline to believe it does not occur in the ordinary undisturbed state of the circulation to any extent. Sir David Barry plunged his arm into the thorax of a horse, and found the aorta constantly full, nearly to bursting, not perceptibly varying in distension for an instant, though he held it during five minutes and examined it afterwards again; while at every expiration the cava was so empty as to feel only like a flaccid thin membrane. [n] The fact of a continued stream occurring from a *wounded* artery, only augmented at each pulsation of the heart, is thought by Magendie [o] to prove that the arteries assist in propelling the blood: but an opening takes off the resistance to its course so considerably that the vessel cannot but contract between the impulses of the heart.

Although the blood is constantly streaming onwards, the pulse is felt only when arteries are more or less compressed; under which circumstance, the motion of the blood onwards, by the impulse of a fresh portion from the left ventricle, is impeded: and this effort of the fluid against the obstructing cause gives the sensation called the pulse [p], which follows the stroke of the heart successively later throughout the arterial system, though the interval is in general too minute to be appreciated. Sir D. Barry found no pulsation in the aorta of the horse unless he compressed it violently.

[m] *On the Blood*, p. 175.

[n] *Dissertation sur le Passage du Sang à travers le Cœur*. Paris, 1827. p. 78. Also, *Annales des Sciences Naturelles*, Juin, 1827.

[o] *Journal de Physiologie*, t. i. p. 110.

[p] *An Experimental Enquiry into the Nature, Causes, and Varieties of the Arterial Pulse*, &c., by Caleb Hillier Parry, M.D. F.R.S. 1816. Likewise a second work, entitled, *Additional Experiments on the Arteries of warm-blooded Animals*, &c., by Chas. Hen. Parry, M.D. F.R.S. 1819.—the latter displays as much talent and learning as the former of originality. Dr. Young, in a Croonian lecture, highly worth perusal, on the functions of the heart and blood-vessels, reasons to prove that the muscular power of arteries has very little effect in propelling the blood. *Phil. Trans.* 1809.

The elastic coat both assists and antagonises the muscular: assists it in preventing distension when the distending force is very strong, and antagonises it — tends to prevent the canal from becoming too narrow — when it attempts to contract the vessel excessively.[q]

Still, independently of the whole quantity of blood, and of the heart's action, particular arteries may be in various degrees of distension, according to the various states of their individual contraction. For example, when a finger has a whitlow, the digital branches are found larger than usual at the very roots of the fingers; in many affections the pulse of the two wrists differ for a time. In fact, their condition may vary like that of the capillaries, and probably does vary every time that altered circulation occurs in a part, although Dr. Parry's opinion holds true during the tranquil and ordinary condition of circulation. I am thus inclined to agree with and differ from both Dr. Parry and Dr. Hastings; believing the former to be right as to the ordinary state, the latter in irregularity. In some diseases the action of the heart is strong and the pulse weak, and *vice versa;* so that it is frequently right to examine both.

The elastic power is said to be greater in the arteries, and the muscular in the capillaries; and as the muscular power is proved by Dr. Parry's experiments to be able to overcome the elastic in the arteries, it must be very considerable in the capillaries.

Dr. Curry, a late lecturer on the practice of medicine at Guy's Hospital, concluded, without doubt hypothetically, from some microscopic experiments which he had made on inflammation in the presence, once of Sir Charles Bell and once of Mr. Travers, that the circulation is indispensably facilitated by a sort of electric repulsion between the vessels and their contents, and that in inflammatory accumulation, the tone of the vessels being impaired, this repulsion is diminished, and the blood passes onwards with difficulty in consequence.[r]

" Since Whytt[s], especially, and other illustrious physiologists

[q] On the operation of the elastic and muscular coats, see J. Hunter, l. c. p. 118. sqq.

[r] See the *Syllabus* of his lectures for 1810.

[s] " Consult his *Physiological Essays, containing an inquiry into the causes which promote the circulation of the fluids in the very small vessels of animals.* Second edition, Edinb. 1761. 12mo.

H. v. d. Bosch, *über das Muskelvermögen der Haargefässgen.* Munster, 1786. 8vo."

have been convinced that the influence of the heart could not reach the extreme arteries and the origins of the veins, they have ascribed the progression of the blood in those vessels to a kind of *oscillation*."

These oscillations are quite imaginary, and now disallowed. Although variations of dilatation must affect the course of the blood through vessels, it is difficult to conceive how any regular action of them can assist it, while the blood is propelled by and drawn to the heart; and the influence of the heart was seen by Dr. Hastings, in some microscopical experiments in which partial obstruction was produced, to extend to arteries, capillaries, and veins, as the blood in them all received a sensible impulse at each contraction of the ventricles. Indeed, we have ocular proof that the capillaries do not contract on the blood in the ordinary state of things; for the blood in them, as well as in the arteries and veins, may be seen for an hour together in the frog's foot, under the microscope, to move in a stream unvarying — neither becoming finer alternately nor experiencing impulses.[t]

In fœtuses without hearts[u], it is not proved that the vascular system carries on the circulation by its own power, because a twin without a heart has never been seen, unless accompanied by a perfect fœtus, whose heart might circulate the blood of both; for placentæ often communicate, so that one child has died of hæmorrhage from the chord of the other: and in the only case where the matter was ascertained[x], the akerious fœtus was actually injected by the navel-string of the perfect fœtus.[y] When, however, the blood is not moved by the heart, the capillaries do impel it. Dr. Wilson Philip once saw it moving freely in some mesenteric capillaries of a rabbit for an hour and a quarter after the excision of the heart[z]; and Haller and Bichat made similar observations.

Mr. Burns[a], anxious to prove that the arteries are of more importance than the heart, that they themselves circulate the

[t] Dr. Hastings, l. c. p. 46. sq. Dr. Magendie, *Journal de Physiol.* t. i. p. 107. sq. says that the blood streams in the arteries and veins of cold-blooded animals, as if the vessels were motionless.

[u] Hewson, *Exp. Enquiry*, v. ii. p. 15. Sir B. Brodie, *Phil. Trans.* 1806.

[x] *Phil. Trans.* 1793. p. 155.

[y] Dr. Young, *Introduction to Med. Literature.* 1823. 2d edit. p. 631. sq.

[z] *An Experimental Enquiry into the Laws of the Vital Functions.* 3d ed. expt. 67.

[a] *Observations on some of the most frequent and important Diseases of the Heart, &c.* By Allan Burns. 1809. p. 117. sqq.

blood which they receive[b], and that the auricles are of more importance than the ventricles, mentions, among other examples of diseased heart, one in which both ventricles were as completely ossified as the cranium, except about a cubic inch at the apex, and in which there had been no palpitation or pain in the heart. As bony ventricles could not contract, nor easily be moved, palpitation could not readily have occurred, and pain rarely attends the ossification of any part. That the circulation was deranged is proved by the woman having experienced great dyspnœa, expectoration, and dropsy. The auricles were healthy, and thicker than usual, and had evidently performed the duty of the ventricles, through which, as an unchanging reservoir between the auricles and the pulmonary artery and aorta, the auricles drove the blood. The invariable languor of circulation in cases where the action of the heart is languid, proves the power of the heart in the circulation.

On the other hand, the large arteries of the extremities are continually found ossified, though not obstructed, without any apparent deficiency of circulation. I have seen long tracts of vessels in the lower extremities ossified, where no such circumstance had been suspected. Mr. Burns himself mentions an instance "of the arteries of the head, pelvis, legs, and arms, being almost entirely ossified[c]," the heart and aorta being healthy; and yet the man clearly died of diseased liver induced by hard drinking, hot climate, &c.

The ventricles are certainly of more importance than the auricles, because these are absent in many animals, and are only reservoirs to supply the ventricles, when the extremities of the great veins at the heart are not of very ample dimensions.[d]

"It remains for us now to examine the aid given to the returning blood by the *veins*, their radicles not being taken into the account. We should conclude at first sight that they have far less active power[e] than the rest of the sanguiferous system, and

[b] l. c. p. 120. [c] l. c. p. 124. sq. [d] J. Hunter, l. c. p. 138.

[e] "What is commonly, but improperly, called the *venous pulse*, observable on opening living animals, and in some morbid affections, and also under a violent effort, does not correspond with the action of the heart, but with respiration; since, if an expiration is unusually deep and lengthened, and the reflux of the blood to the lungs thus impeded, the jugular vein swells as far as the brain, the subclavian as far as the basilic, and the inferior cava as far as the crural." But there is also in some diseases of the heart a pulse of the lower portion of the external jugulars, synchronous with the systole of the ventricles, and dependent, as already explained, on the interrupted progress of the blood to the ventricles during their contraction. A vein may pulsate from its proximity to an artery.

that the return of their purple blood to the heart is chiefly ascribable to the impetus a tergo of the arterial blood, and to their valvular structure, which prevents any reflux. The efficacy of the valves in this point of view, is shown by the distensions and infarctions of the veins in the lower part of the abdomen, which are found destitute of valves.[f]

"The existence of vital powers in the venous trunks is probable[g], from the example of the liver and placenta, and from experiments instituted on living animals. We formerly mentioned the muscular layer in the extreme veins near the heart."

In a young lady, whom I attended, before the days of auscultation, for chronic bronchitis accompanied by violent cough, and who ultimately recovered, *all* the veins of the back of the hands and fore-arms distinctly pulsated synchronously with the arteries. Hunauld and Laennec each saw a similar case.[h] An universal pulsation of the veins synchronous with that of the arteries, occurred for some days twice in a young man who died of cerebral disease, with constriction of the mouth of the aorta[i]; once in a middle-aged man with affections of the head and abdomen, who recovered[j]; once in a middle-aged man who died with dropsy and palpitation[k], and in a girl who died with symptoms of hydrocephalus.[l] In a case of epidemic fever, the same was observed by Weitbrecht for twenty-four hours[m]; and he had previously seen a similar case, but doubted his senses. Haller's remark upon it is, "Ego quidem non intelligo."[n]

In venesection at the bend of the arm, I have frequently seen the jet regularly stronger at each pulsation of the heart; and J. Hunter mentions the same thing, and states it to be more observable at the head or foot, saying, "The fact is, however, that there is a pulsation in the veins.[o]

Yet ordinarily there is, speaking of the veins in general, no venous pulsation, and the stream in the veins, though caused

f "G. E. Stahl, *De vena portæ porta malorum*. Halæ, 1698. 4to."

g "Lister, *De humoribus*, p. 25."

h Laennec, l. c. p. iii. s. ii. ch. ii.

i *Journal Complimentaire*, t. 21. June, 1825.

j *Journal der Praktischen Heilkund*. Sept. 1815.

k *Archiv. für Medinische Erfahrung*. July and August, 1822.

l *Dublin Hospital Reports*, vol. iv.

m 1736. Haller's *Disputationes*, t. v. p. 407.

n *El. Phys.* t. ii. p. 356.

o l. c. p. 186. sq.

mainly by the left ventricle, — as may be seen by tying all the vessels of an extremity but the artery, and wounding the vein, when the jet from the vein may be regulated by pressing the artery, — is perfectly uniform. By the infinite subdivisions and great increase of capacity of the arterial system, the blood, which is moved in jerks in the larger arteries, giving a pulse, and, if the vessel is wounded, flowing more forcibly at the heart's pulsation, gives no pulse in the small vessels, and, if they are wounded, flows regularly ; and in the capillaries, through the augmentation of space, experiences no increased momentum at the heart's pulsation. When the capillaries unite into veins, and the capacity of the whole vascular channel diminishes, the blood moves more quickly again through the diminished space[p]; but, though the smaller space augments its flow again, the impulses of the heart lost in the capillaries cannot be felt in the veins, and the current in them is smooth. Neither, generally speaking, is it by any means so rapid as in the arteries, because much of the heart's force is expended, and the veins are generally so much more numerous than the arteries, and the space, therefore, however less than in the capillaries, still much greater than in the arteries. Nor ought the momentum to be strong when the veins have all united into the cavæ, because it has only to reach the heart, where there is no resistance, but, on the contrary, more than one source of vacuum prepared; whereas in the aorta it ought to possess a force sufficient to carry it a great distance, and surmount great obstacles.

When the veins have pulsated, the action of the heart must have been very violent, or some obstruction occurred, which, in Dr. Hastings's experiments, was seen to cause the heart's action to be sensible in the capillaries and veins.[q]

There is always a pulsation in the large veins near the heart: but that arises from obstruction, as I have already mentioned.

" These are the chief powers which move the blood, and depend upon the structure and vitality of the sanguiferous system. We say nothing of the effect of gravity, attraction, and other properties, common to all matter. The more remote assistance derived after birth from particular functions, *v. c.* respiration and muscular motion, will appear in our account of those functions."

[p] Dr. Hastings, when observing the circulation in the frog's foot under the microscope, saw that the blood moved " faster in the arteries than in the veins, and in the veins than in the capillaries." l. c. p. 47.

[q] l. c. p. 47. sqq.

The heart of *mammalia* and *birds* has no peculiarity necessary to be mentioned here. In most *amphibious animals*, the arteries of the system as well as of the lungs spring from the right ventricle, with which the left, that sends off no vessel, communicates: hence their circulation continues under water. In *amphibious mammalia* and diving birds, some vessels, especially one vena cava, are dilated, to form a receptacle during the suspension of respiration. The heart of *fish* is extremely small, and has but one auricle and ventricle, the latter propelling the blood to the gills, from which it streams to the system through a large artery. Neither blood-vessels nor absorbents have been discovered in *insects*, yet a large tube pulsates in their back; and Professor Carus has lately discovered a circulation in them through a granular substance, the streams running to the posterior end of this vessel, and issuing again from its anterior end. With respect to the *mollusca*, the cuttle-fish has three detached hearts, consisting of a ventricle only, two for the gills and one for the aorta; the rest have a simple heart, the blood of the cava passing through the gills before it reaches the heart. The same is the case with the *crustacea*, and their heart has no auricle. *Worms* have circulating vessels distinctly contracting and dilating, but no heart, and their veins communicate with the general cavity of the body, and probably absorb. *Zoophytes* have no heart, nor circulating system, properly so called. In the echinus, indeed, there are two vessels that run along the intestines, and are thought to be an aorta and vena cava. But currents may occur, and not be perceptible if the fluid is colourless, or has no globules; and currents have been lately discovered by Mr. Lister in some zoophytes exactly similar to the currents long observed under the microscope in the tubes of stone-wort; the streams running first in one direction, on the internal surface of a tube, and then returning in another on the same surface. Such streams on surfaces or through cells are very wonderful.

According to Dr. M. Hall, when the office of a part in brutes is simple, the distribution of blood-vessels is simple, as in the fin or tail of a fish, and the arteries chiefly become veins: but when its office is complicated, as in the toes of the frog, or the blood has to be thoroughly exposed to air, as in the lungs, the arteries give off a number of branches, which do not diminish in diameter or give off others, and are peculiarly called by Dr. Hall capillaries, as large as, or larger than, their parent branch, freely anastomosing, not diminishing in size, nor giving origin to or running into the sides of veins. In the lungs, the large vessels presently split into capillaries; in the systemic arteries, the vessels diminish and subdivide considerably beforehand.

Vegetables have no central organ of circulation. The sap rises ordinarily through the cells, or, according to Decandolle, the intercellular spaces of the wood. Some plants are altogether cellular. The vessels in the wood of those which are vascular are found to contain air only, and the sap sometimes takes so circuitous a route, is so diffused, and so subsides to the lowest parts, that it cannot, in all cases at least, be confined to vessels. The sap rises chiefly in the newest layer of wood, called alburnum. But when the buds are preparing for developement, and the leaves are not yet complete, the sap is termed nursling sap, and ascends through the oldest and innermost layer of wood, and passes through unknown channels to the buds, combining probably with nutriment formerly deposited. This nursling sap has been compared to the milk elaborated for the young of animals. The returning or descending sap passes through either vessels or intercellular spaces, chiefly along the innermost layer of bark, and some along the outermost layer of wood, where it must mix more or less with the ascending sap. In cellular plants, of course, the passage cannot be through vessels, and perhaps it passes through cellular tissue in all. The motion of the sap both in cellular tissues and vessels is explained, according to M. Raspail, by the fact of the inner surfaces of the cells and vessels of vegetables, &c. absorbing and exhaling rapidly, by which motion is given to the fluid and a current is established. (l. c. p. 317. sqq.) The power propelling the sap is such, that, if a piece of the stem is cut out, it entirely empties itself; and the sap has been found to flow from the extremity of a branch with a force sufficient to overcome a column of water 43 feet $3\frac{1}{3}$ inches in height. (Hales, *Statical Essays*, vol. i. p. 101.)

It would not be right to terminate this section without a note upon the discovery of the circulation of the blood;—a truth of which the ancients are thought to have remained ignorant, from finding the arteries empty after death. But they knew that these contained blood during life, as Galen (*De Anat. Admin.* vii. 15.) relates some amusing anecdotes of his pupils and some persons who promised to prove the arteries empty. The discovery was made by our countryman, Dr. Harvey, Physician to St. Bartholomew's Hospital, and promulgated by him at the age of forty-one, in an anatomical and surgical course of lectures at the College of Physicians, in 1619. He is entitled to the glory of having made it, says Hume (*History of England*, ch. 62.), "by reasoning alone, without any mixture of accident." He informed Boyle, that he was led to it by reflecting on the arrangement of the valves of the heart and veins, as exhibited by his master Fabricius. Nothing, he knew, was planned in vain, and they clearly allowed a fluid to pass but one way. By this argument, and the fact of a ligature upon an *artery* causing the blood to accumulate in it on the side *nearest* the heart, and, upon a *vein*, *beyond* the ligature; and that animals bleed to death by wounds in arteries or veins, he chiefly established his doctrine. After his time it was demonstrated with the microscope in cold-blooded animals. His immediate reward was general ridicule and abuse, and a *great* diminution of his practice [r]; and no physician in Europe, who at the time had reached forty years of age, ever, to the end of life, adopted his doctrine of the circulation of the blood. (Hume, l. c.) When the truth could be denied no longer, he was pronounced a plagiarist; the circulation was declared to have been known to Plato; nay, more, to king Solomon. (See Haller, *El. Physiol.* t. i. p. 243.) The circulation through the lungs had certainly been taught about

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[r] This he laments in a letter to a friend, as may be seen in a MS. of the Royal Society, referred to in the Life prefixed to the College edition of his works: — "Quod multo rarius solito ad ægros invisendos accersitus esset, postquam librum de motu cordis ediderit."

seventy years previously by Servetus[s], a Spanish physician of great anatomical knowledge, and original and active mind[t], who was *slowly* burnt to death, Oct. 27. 1553, the fire being made to last two hours by means of wood small in quantity and green, through Calvin, for not happening to be in all his writings of the same opinion as himself upon a point in divinity. Calvin was honourable enough to produce private letters in evidence of the difference of the opinions of Servetus from his own, and fancied himself to be a Christian.

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[s] His words are,—"sanguine, quem dexter ventriculus cordis sinistro communicat. Fit autem communicatio hæc, non per parietem cordis medium, ut vulgo creditur, sed magno artificio, a dextro cordis ventriculo, longo per pulmones ductu, agitatur sanguis subtilis; et a vena arteriosa, in arteriam venosam transfunditur. Deinde, in ipsa arteria venosa inspirato aeri miscetur, *expiratione a fuligine repurgatur.* Atque ita tandem a *sinistro cordis ventriculo totum mixtum per diastolem attrahitur,* apta suppellex, ut fiat spiritus vitalis. Quod ita per pulmones fiat communicatio et præparatio, docet conjunctio vario, et communicatio venæ arteriosæ cum arteria venosa in pulmonibus. Confirmat hæc magnitudo insignis venæ arteriosæ, quæ nec talis, nec tanta facta esset, nec tantam a corde ipso vim purissimi sanguinis in pulmones emitteret ob solum eorum nutrimentum, &c. Item, a pulmonibus ad cor non simplex aer, sed mixtus sanguine mittitur per arteriam venosam: ergo, in pulmonibus, fit mixtio, &c. Illa itaque spiritus vitalis, a sinistro cordis ventriculo, in arterias totius corporis deinde transfunditur, &c. Sicut, in transfusione a venis in arterias, est in pulmone novum genus vasorum, ex vena et arteria, &c." If we could be satisfied that by *spiritus vitalis* Servetus meant blood, we should say that he had also described the general circulation, because he mentions the course of the vital spirit from the left ventricle into the arteries throughout the body, and the course of the blood from the right side of the heart implies the course of it from the body or some part to the right side of the heart. The expressions *per diastolem attrahitur* might almost persuade us that he was acquainted with the influence of the vacuum from the expansion of the ventricles: and his account of the office of respiration to liberate the blood from its soot, *expiratione a fuligine repurgatur,* completely agrees with the discovery of the separation of carbon; while the doctrine that *a pulmonibus ad cor, aer, mixtus sanguine, mittitur per arteriam venosam,* accords with the present doctrine of the absorption of a portion of the air.

I am indebted for this most interesting quotation to the *Medical Dissertations* of Dr. Sigmond (ed. 2. 1828), who possesses a copy of Servetus bequeathed to him by Dr. Sims, for many years President of the London Medical Society, and supposed by Dr. Sims to be the only copy not burnt by the furious Calvin; to have been secreted and saved by Dr. Colladon, one of the judges; to have passed to the Landgrave of Hesse-Cassel, and then to Dr. Mead, who had nearly completed a quarto edition of it, when, at the instance of Gibson, Bishop of London, the edition was seized, May 27. 1723, and burnt, with the exception of a very few copies. The Duc de Vallière gave nearly 400 guineas for the book, and at his sale it brought 3810 livres. Dr. Sigmond, however, does not believe it to be the original copy.

[t] In the words of an Harveyan oration by Sir George Baker, "Vis illa animi tam vivida, tam libera et erecta, impatiens magistri."

CHAP. XII.

RESPIRATION, AND ITS PRINCIPAL USE.

"THE *lungs*[a], closely connected with the heart both by proximity and by relation of function, are two viscera," of the shape and size of the thorax, which they fill; with a very large base, like a horse's hoof; the right divided into three lobes, the left into two; "so light as to swim in water, and composed of a spongy, but pretty tenacious and elastic[b], parenchyma."[c]

Like other cavities, the chest is lined by a serous membrane, by which is meant a close sac, translucent [d] during life and health, and coherent by cellular membrane externally with every thing in contact,—with parietes and viscera; internally smooth, unattached, in contact only with the opposite portions of itself, and moistened by serum.[e] A serous membrane thus affords an external coat to viscera, insulates them, and facilitates their movements.

Each lung has a serous membrane, called Pleura, so that the pleuræ are two closed sacs, one of which lies over each lung,

[a] "Soemmerring and Reisseisen, *über die Structur, die Verrichtung und den Gebrauch der Lungen. Zwey Preischriften*. Berlin, 1808. 8vo."

[b] "J. Carson, *On the Elasticity of the Lungs*, in the *Phil. Trans.* 1820. p. 29. Consult also, Const. Ern. de Welzien, *De Pulmonum autenergia, &c.* Dorpat, 1819. 8vo."

[c] "Respecting all the organs concerned in respiration, consult Corn. J. Van Den Bosch, *Anatomia Systematis Respirationi inservientis Pathologica*. Harlem, 1801. 4to. pp. 1—44."

[d] M. Richerand tells us, that, on removing a portion of the thorax when cutting away a cancer, he saw the heart through the pericardium. *Journal de Médecine*, 1818.

[e] Dr. Marshal, from many experiments, believed that this is not the case, but that, whenever fluid is discovered, we must regard it as the effect of either disease or the struggle of dying. His experiments were made on the ventricles of the brain, the theca vertebralis, the pleura, and the pericardium (*The Morbid Anatomy of the Brain in Mania, Hydrophobia, &c.*); yet, when Dr. Magendie has opened the membranes of the brain or spinal marrow, I have myself seen a colourless clear fluid instantly escape.

one portion of the sac adhering closely to it, and one lying over this again; the internal surfaces of both portions are always in contact, because, if the parietes of the thorax expand and draw with them the external portion, the lung at the same time expands with air and forces forwards the internal in the same degree.

The union of the two pleuræ, from the sternum to the spine, is called the septum or mediastinum. The heart lies between the two. Before the two unite at the posterior part, they leave a cavity, called the cavity of the posterior mediastinum, containing the aorta, œsophagus, thoracic duct, vena azygos, large bronchiæ, lymphatic ganglia, and cellular membrane. In front, they leave another space, called the cavity of the anterior medastinum, which contains cellular membrane, and in the fœtus the thymus gland.

"The lungs hang, in a manner, from the wind-pipe, usually called aspera arteria or trachea," "which is composed of an internal mucous membrane continuous with that of the fauces, of an external fibrous membrane, and of from fifteen to twenty fibro-cartilaginous falciform arches, imperfect at the posterior part, where transverse muscular fibres connect the two extremities of each cartilage. Within this muscular coat, and throughout the trachea and bronchiæ, a coat of longitudinal fibres is seen.

"The aspera arteria, having entered the thorax, is bifurcated" (the right branch the shorter and wider) "opposite the third dorsal vertebra," "into the trunks of the bronchiæ, and these, the more deeply they penetrate into the lobes and lobules of the lungs, are the more and more ramified;" the fibro-cartilaginous rings are, each divided into pieces, more and more numerous and smaller, till they are mere grains, and at length are lost, together with the external fibrous coat; and the extreme divisions, consisting of the mucous membrane, and probably of the circular longitudinal fibres immediately external to it, terminate in those *cells* which form the chief part of the substance of the lungs and alternately receive and emit the air we breathe.

"The shape and magnitude[f] of the air-cells are various. The former is generally polyedrical. The latter, in regard to surface, is scarcely to be defined[g]: though, indeed, the *capacity* of the lungs of an adult, during a strong inspiration, is about 120 cubic

[f] "Keil, indulging his luxuriant iatro-mathematical genius, assigned more than 1,744,000,000 cells to each lung."

[g] "Lieberkühn, with equal exaggeration, made the surface of the cells equal to 1500 square feet."

inches. The immense size to which the lungs may be inflated, when the chest has been opened, has no relation to our present subject.

"The cells are invested and connected by the common but delicate cellular membrane — the general vinculum of the body — and must be carefully distinguished from it. In healthy and very recent lungs, I have found the cells so unconnected that they were distended in one insulated spot by air cautiously inflated into a fine branch of the bronchiæ, while neither the neighbouring cells nor the cellular membrane, which lies between the cells, admitted the smallest portion. If air is forcibly thrown in, the air-cells are ruptured and confounded with the cellular membrane, and both parts distended.

"The cellular membrane surrounding the air-cells of the lungs is supplied with innumerable blood-vessels — divisions of the pulmonary artery and four pulmonary veins, the branches of which accompany the ramifications of the bronchiæ[h], and, after repeated division, form at length an immense collection of most delicate and reticulated anastomoses. This extraordinary network, penetrating the mucous web on every side, closely surrounds the air-cells, so that the prodigious quantity of blood existing in the pulmonary vessels is separated from the contact of the air by very fine membranes only, which Hales estimated as scarcely $\frac{1}{1000}$ of an inch in thickness.

"As each ramification of the bronchiæ possesses its own bunch or lobule of air-cells, so again each of these possesses a peculiar system of blood-vessels, the twigs of which anastomose in the wonderful network with one another, but scarcely at all with the blood-vessels of the other lobules, as is proved by microscopic observations on living frogs and serpents, by minute injections, and by the phenomena of vomicæ and other local diseases of the lungs."

The best treatise with which I am acquainted upon the lungs, is the prize commentary of Reisseisen, published by the Royal Academy of Sciences at Berlin in 1808, and printed in 1822, with six beautiful coloured engravings, and a Latin version, under the care of Professor Rudolphi.[i]

[h] "Eustachius, tab. xxvii. fig. 13."

[i] Francis Daniel Reisseisen, M.D. of Strasburgh, *über den bau der Lungen, eine von der Königlichen Academie der Wissenshaften zu Berlin gekrönte Preiss chrift.* Berlin, 1822.

He asserts, 1st, That the subdivisions of the bronchiæ occur more and more thickly, the twigs proportionally decreasing in diameter and length, and that each ultimate twig ends in a close bulbous extremity, or cell, communicating with other bulbous extremities only in an indirect manner, — by means of the twigs which end in them. Malpighi had described them as round, and mere dilatations in the course as well as at the ends of the bronchial twigs.[k] 2d, That, as Malpighi proved, and contrary to the subsequent opinion of Helvetius and others, these ramifications and cells have no connection with the surrounding common cellular membrane. 3d, That they consist of, — 1. *mucous membrane*, behind which lies, — 2. a coat of *elastic* white fibres, their existence being visible as far as the canals can be traced, and the regular discharge of any fluid injected into the bronchiæ after death proving the existence of elasticity in the bronchial ramifications ; — 3. a coat of *muscular* fibres, transverse relatively to the course of the canals, and visible by the aid of a magnifier as far as the size of the canals will allow them to be traced. He conceives the muscularity of the twigs and cells to be shown also from the necessity for its existence in them no less than in the large trunks and trachea, where it is visible ; from their evident contraction in the experiments of Varnier, who irritated them by the injection of stimulating liquids and gases, and by mechanically stimulating the surface of the lungs[l]; and from the circumstance of the lungs shrinking much more if an opening is made in the thorax of a living than of a dead animal, in the latter of which it can shrink from elasticity only. 4th, That the ramifications of the bronchial and pulmonary arteries freely anastomose both in the air-passages and on the surface of the lungs, and that the bronchial arteries run chiefly direct to the pulmonary veins. 5th, That the air-passages and blood-vessels of the lungs are most abundantly supplied with nerves from the par vagum, whose conjunctions with the sympathetic take place externally to the lungs.[m]

“ The common membrane investing the lungs is the chief seat of a remarkable network of lymphatic vessels [n] which run to nu-

[k] *Epist. de Pulmon.* 1. p. 133.

[l] *Mémoires de la Société Royale de Médecine*, 1779. p. 394. sqq.

[m] Some other conclusions are drawn, but unimportant or unsatisfactory.

[n] “ Mascagni, *Histor. vasor. lymphaticor.* tab. xx.”

merous lymphatic or conglobate glands[o], carefully to be distinguished from a neighbouring order of glands, called bronchial, that are supplied with an excretory duct opening into the mucous membrane of the bronchiæ, and are of the conglomerate kind.[p]

"The *thorax*, which contains the lungs, has an osseous and cartilaginous framework," narrow above and broad below, "somewhat resembling a bee-hive, throughout very firm and stable, but in every part more or less movable for the purpose of respiration."[q]

The framework is the twelve dorsal vertebræ, forming a column convex externally, concave in front; the twenty-four ribs, also convex externally and concave within; and the sternum: all the ribs are united at one extremity by a joint with the dorsal vertebræ; the seven highest ribs are connected at their other extremity with the sternum by means of a cartilage, larger and longer in each lower rib, just as each of the seven ribs is longer than the rib above it (true or sternal ribs), and the three next are each united by cartilage with the cartilage of the rib above (false or asternal ribs), and the two lowest have their anterior extremity unattached (floating false or asternal ribs). When the

a, vertebræ of spinal column.
b, sternum.
c, ensiform cartilage.

[o] "Ibid. tab. xxi."

[p] "Consult Portal, *Mém. de l'Acad. des Scienc. de Paris.* 1780."

[q] "J. G. Amstein (Præs. Oetinger), *De usu et actione musculor. intercostal.* Tubing. 1769. 4to. Theod. Fr. Trendelenburg, Jun. *De sterni costarumque in respiratione vera genuinaque motûs ratione.* Gotting. 1779. 4to.
Bordenave and Sabatier, *Mém. de l'Acad. des Scienc. de Paris.* 1778."

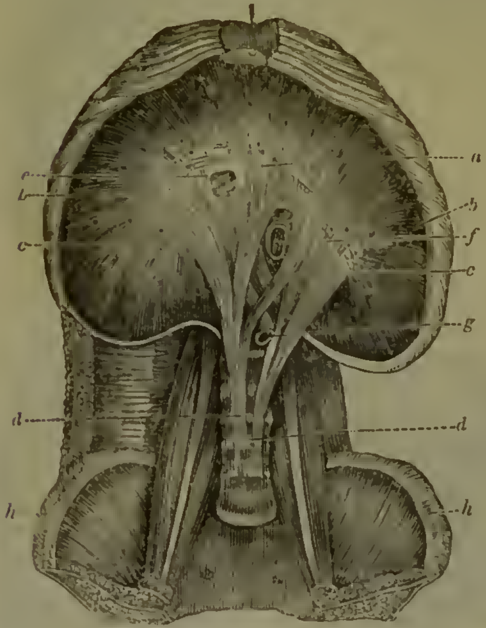
ribs are raised, their vertebral extremity rotates, remaining in its place; the rest of the rib rises, each part of course the more, the more distant it is from the vertebra, and the lower margin is drawn rather outwards; and with the ribs the sternum rises. The chest thus becomes both *broader* and *deeper* from front to back.[r]

" Between the edges of the ribs lie two strata of intercostal muscles, differing in the direction of their fibres, but conspiring" to elevate the ribs or depress them, just as the higher or lower rib happens to be the more fixed. The one is external, placed between the vertebræ and the cartilages, and its fibres run forwards and downwards: the other internal, placed between the sternum and the angle or curve of the rib near the spine, and its fibres run downwards and backwards. Ordinarily, they act as muscles of inspiration, and raise the ribs, because the lower rib is more movable than the one above it.

Between the higher and middle rib, except near the sternum, is seen the internal intercostal: between the lower and middle, the external.

[r] Although each lower rib among the first eight must execute a greater extent of motion, from being longer than the one above, yet the first is asserted by Dr. Magendie to be absolutely more movable than the second, the second than the third, &c.; and this because the first has but one articular surface, is articulated with but one vertebra, and possesses neither internal nor costo-transverse ligament, and has the posterior ligament horizontal, and because slight shades of difference exist in the disposition of the ligaments of the six other ribs. *Précis Elémentaire*, t. ii. p. 317.

"At the base of the thorax, the diaphragm[5] is subtended in the form of an arch." The central part is tendinous, and has an irregularly quadrilateral opening rather to the right, for the transmission of the vena cava, which adheres to its margin and is thus kept open. From this tendinous centre, muscular fibres proceed in all directions, and the anterior and lateral are inserted into the ensiform cartilage and six lowest ribs and their cartilages, while the posterior fibres converge into two great bands, called pillars of the diaphragm, which run downwards and are inserted by means of two tendons into the three first lumbar vertebræ. At their origin they leave an oval opening between them for the passage of the œsophagus and pneumo-gastric nerves, each bunch sending a bundle across to the other in order to complete the opening behind. More posteriorly, near their termination in tendon, they leave a parabolic opening for the aorta, vena azygos, and thoracic duct.



a, central tendon.
b, surrounding muscle.
c, crura.
d. tendons of crura.
e, opening for vena cava.
f, opening for œsophagus.
g, space for aorta.
h, ossa *ilii*.

When the fibres contract, the diaphragm descends, chiefly at its sides, and ceases to be vaulted, and the cavity of the chest *lengthens*. It is the lateral portions only which in ordinary inspiration sensibly descend.

[5] "Haller, *Icon. Anat.* fascic. 1. tab. i.
B. S. Albinus, *Tab. musculor.* tab. xiv. fig. 5, 6, 7.
J. G. Röderer, *De arcubus tendineis muscul.* progr. 1. Gotting. 1760. 4to.
Santorini, Tab. Posth. x. fig. 1."

"It is a considerable muscle, and, in the words of Haller, next in importance to the heart. Its utility in the mechanical part of respiration was long since shown, by the excellent experiments of Galen [t] upon living animals, to depend chiefly on the phrenic nerve.[u]

"Its antagonists are the abdominal muscles, especially the two sets of oblique and the transverse.

"The thorax, thus constituted, is, after birth, dilated by inspiration, and subsequently reduced to a smaller capacity by expiration.

"During the former act, the thorax is enlarged laterally and inferiorly, so that the bodies of the six ribs mentioned above are elevated and their inferior margin drawn somewhat outwards; the arch of the diaphragm is at the same time rather depressed and flattened."

The lungs in ordinary respiration do not descend lower than the sixth rib, and the lateral portions of the diaphragm, ascending into the empty space, lie in contact on both sides with the lower ribs, each covered by its costal pleura.

Dr. Carson gives the following account of the mechanical part of respiration.

The substance of the lungs is highly elastic, and constantly kept in a forced state of distension after birth by the pressure of the atmosphere.[x] This is evident also from the lungs collapsing upon our puncturing the walls of the thorax, — a circumstance arising from the atmospheric pressure on the one hand becoming counterbalanced on the other, so that their elasticity, experiencing no opposition, becomes effective.[y] During inspiration, the intercostal muscles raise and draw out the ribs, and the diaphragm descends: the enlargement of the thoracic cavity is instantly followed of necessity by the greater distension of the substance of the lungs from the diminished resistance to the atmosphere gra-

[t] "*De Anatomicis Administrationibus*, l. viii. cap. 8. The whole book is very rich in experiments on respiration."

[u] "Ephr. Krüger, *De nervo phrenico*. Lips. 1759.; reprinted in Sandifort's *Thesaurus*, tom. iii.

Walter, *Tab. nervor. thorac. et abdominis*, tab. i. fig. 1. n. 1."

[x] See Haller, *El. Phys.* lib. viii. s. iv. pp. 259. 275.

[y] Dr. Carson found the elasticity of the lungs of calves, sheep, and large dogs balanced by a column of water of from a foot to a foot and a half in height, and of rabbits and cats by a column of from six to ten inches. *Phil. Trans.* 1820. Part 1.

vitating in the bronchiæ. The diaphragm and intercostal muscles ceasing to act, the substance of the lungs exerts its elasticity with effect, recovers its former dimensions, and drives out the additional volume of air just admitted, and the passive *diaphragm* follows the shrinking substance of the lungs, offering, from its relaxation, no resistance to the atmosphere pressing on the surface of the abdomen. Thus expiration is produced. The muscular power of the diaphragm and intercostal muscles is far greater than the elastic power of the lungs, and therefore, when exerted overcomes it, producing inspiration: but, ceasing to be exerted, the elastic power gains efficiency, and produces expiration.

To the elastic, Reisseisen adds the muscular, contraction of the bronchial ramifications and cells. "Thorace ampliato, aër vacuum in pulmone spatium occupat, *victisque fibris*, fistulam spiritalem quaquaversum extendit, ultra modum, quo quiescit, explicari coactam, unde fibræ *elasticæ resilire*, circulares sese contrahere nituntur, quo fit ut desidente thorace omnes simul ad expellendum spiritum vires intenduntur. Sunt autem, thoracis undique desidentis pressio, tum fibrarum fistulam spiritalem in brevius contrahentium vis *elastica*, denique *muscularium* illam constringentium *irritabilitas*.

"The contractile power of the diaphragm (*and intercostal muscles*), in conformity with the laws of muscular motion," says Dr. Carson [z], "is irregular, remitting, and sometimes altogether quiescent. The elasticity of the lungs, on the other hand, is equal and constant. The superior energy of the former is balanced by the permanency of the latter. By the advantage which the inferior power, from the uniformity of its operations, is enabled to take of the remissions of its more powerful antagonist, the ground which had been lost is recovered, and the contest prolonged; that contest in which victory declaring on one side or the other is the instant death of the fabric."

In the common account of respiration, the elasticity and muscularity of the lungs are unnoticed, and expiration is ascribed to the elasticity of the cartilages of the ribs, and to the contractions of the abdominal muscles emptying the lungs by pressure. Now, according to Dr. Carson, in the first place, the elasticity (*and muscularity*) of the lungs is of itself sufficient for the purpose; in

[z] l. c. p. 223.

the second, there is no proof of the agency of the abdominal muscles in expiration; it proceeds equally well in cases of inanition, when their contraction would rather enlarge than diminish the abdominal cavity, and in experiments when they are entirely removed from animals, — a child was born without them, and had lived eighteen months at the time of the publication of its case, and was very well[a]: and I may add, thirdly, that, although the elasticity of the cartilages of the ribs must conspire with that of the lungs, numerous cases are recorded of immobility of the ribs, by ossification of their connections, where respiration was not materially impeded.[b] These cases are adduced to show that the diaphragm is the chief instrument of respiration; but, as its elasticity cannot produce expiration, they show that this was accomplished entirely, or in a great measure, by the lungs themselves. Even where there is no ossification, the motion of the ribs has very little share in respiration; and Dr. Bostock considers the chief use of the intercostals to be that of giving a fixed point for the action of the diaphragm, and the operation of the abdominal muscles in expiration to be nearly passive.[c] It is commonly known, however, that, if the pleura is wounded, air rushes into the chest during inspiration only, and is in some measure expelled again during expiration. Galen showed this, notwithstanding his object was different, by wounding the chest and fixing a bladder upon the wound. The bladder shrunk at inspiration, and became distended at expiration.[d] Were the ascent of the diaphragm and descent of the ribs in expiration the *effect* of solely the contraction of the lungs — of a tendency to vacuum occasioned by their shrinking, — air and fluids should stream to the chest as much during expiration as inspiration — should rush to fill up the vacuum as much as the diaphragm should ascend and the ribs descend for that purpose: nor should air be expelled from the wounded pleura; for we may regard the thoracic cavity

[a] *Gazette de Santé,* Dec. 5. 1826. A child of seven years is *said* in Lieutaud to have had no diaphragm.

[b] Dr. Bostock, *An Elementary System of Physiology,* vol. ii. p. 15.

[c] l. c. vol. ii. pp. 7. 15.

[d] *Administ. Anat.* lib. viii. c. ult.

If, instead of a bladder, a tube immersed in a coloured fluid is employed, this will of course rise in inspiration, and remain stationary or fall in expiration. See *Experimental Researches on the Influence exercised by Atmospheric Pressure upon the Progression of the Blood in the Veins, &c.* By Edward Barry, M.D. London, 1826.

as bounded above by the surface of the lungs, and always in the sound state possessing the same dimensions, — the expansion of the lungs being commensurate with the descent of the diaphragm and ascent of the ribs, and the descent of the diaphragm and ascent of the ribs commensurate with the shrinking of the lungs. The fact that air does not stream into the wounded pleura in expiration, but even streams from it, while the ribs are moveable and the abdominal muscles active, proves, I think, that the descent of the ribs and ascent of the diaphragm, one or both, in ordinary expiration, do partly occasion, by compression [e], the diminution of the lungs, or, at least, are not its passive effect, but coincide with it by independent powers,—which are, the elasticity of the elevated ribs (and displaced abdominal organs ?), if not the contraction of the extended abdominal muscles. We shall presently see another reason for believing that the organs of the chest are really compressed during expiration. Haller refers expiration to the pressure of the lungs by the elastic ribs and the abdominal and other muscles, and to the elastic and muscular contraction of the lungs themselves, which he considers more forcible than the compression. It appears to me that he is right; but that, nevertheless, either the lungs alone, or the walls of the chest alone, are able, when unassisted by the other, to produce expiration. The change in the situation of the ribs is, moreover, trifling compared to that of the diaphragm, and respiration often proceeds very well by the diaphragm alone. Animals which are remarkable for swiftness and perseverance in the race scarcely employ the intercostal muscles, using the diaphragm almost solely.[f]

The beautiful contrivance in the shape of the thorax deserves attention. By its being conical, every degree of motion in the diaphragm produces a greater effect on the capacity of the chest than could occur were it of any other shape.

The passage of the air into and from the cells may be distinctly heard on applying the ear to the corresponding part of the chest, and is called by Laennec the respiratory murmur. It is much louder in children, and in them the cells are far more numerous and small. Whence an equal portion of lung from an infant a few days old weighs fourteen times more than from a man of seventy.[g] When the air tubes are constricted or supplied with too copious

[e] l. c. lib. viii. sect. iv. p. 275. sq.

[f] Dr. Carson. l. c. p. 226. In disease I have seen the diaphragm regularly relax when the intercostals contracted, and contract when they relaxed. Any one may readily make them act oppositely.

[g] Dr. Magendie, *Journal de Physiologie*, t. i. p. 81.

or with diseased secretion, the respiration is heard with various sounds, rough and snoring (sonorous rattle), shrill, squeaking, chirping, hissing (sibilant rattle), gurgling (mucous rattle); and, if too much fluid exists in their extremities or the air-cells, we hear a crackling sound (crepitant rattle). If the tubes are quite obstructed, or the lung compressed by air or fluid in the pleura, or by a solid, or if they are solidified, we hear no respiratory murmur. In the three latter cases, the walls of the chest, when struck at the spot affected, do not give out the hollow sound which the presence of air in the lungs naturally gives, but are as dead as if any solid muscular part was struck. These and many similar facts, discovered by Avenbrugger [h] and Laennec, are of the highest utility in detecting diseases of the chest, exist by physical necessity, and, being facts, are just as important to the medical philosopher as any other symptoms; and though some, who have contrived to acquire a name among the ignorant, may affect to despise them, the rising generation feel justified in ascribing their contempt to indolence, conceit, and ignorance—an ignorance so disgusting, that it must eventually reduce them to their proper level.

The elasticity and muscularity of the lungs are not sufficiently great to expel the whole of their air in expiration. Thus they remain constantly in a certain degree of distension. [i]

I now recur to the subject of the circulation of the blood, as promised in the last chapter.

The vacuum constantly threatening in the chest, according to Dr. Carson, either from the shrinking of the lungs or the contraction of the inspiratory muscles, and, I may add, from the expulsion of blood from the ventricles of the heart, will evidently be prevented, not only by the falling of the ribs and the ascent of the diaphragm in the former case, and ingress of additional air into the bronchiæ in the latter, but also by the flow of venous blood into the auricles: for the venous blood, being subject to the full atmospheric pressure without the chest, will necessarily be driven into the chest to prevent a vacuum [k]; the blood of the

[h] *Inventum novum ex percussione thoracis humani, abstrusos interni pectoris morbos detegendi.* 1761.

[i] Reisseisen, l. c. p. 23.

[k] See Dr. Huxham. *Observationes de Aëre et Morbis Epidemicis.* Londini, 1751. Prolegomena, p. 7. sqq. "Facto nempe in ductibus pulmonum sanguineis mo-

pulmonary artery and aorta is under the same circumstances, but the propelling force of the ventricles at one moment, and the action of their valves during their relaxation, prevent its retrogression. The atmospheric pressure on the blood-vessels creates a necessity for greater strength in the ventricles, as it impedes the progress of blood from the heart; but it also facilitates the return. Thus the smaller pressure on the heart acts, by the intervention of the blood, as an antagonist to its contracting fibres, assisting to dilate them when they become relaxed.

That the blood is drawn towards the heart during inspiration has been long acknowledged. "In my experiments," says Haller, "if you open the chest, abdomen, neck, or fore-extremities of an animal, and lay bare the great veins, the superior and inferior cava, the jugular, subclavian, brachial, or mammary, you will see the blood return to the heart *whenever the animal inspires*, and these veins recede some lines from it, become empty and pale, flat and bloodless:" — depleri, palescere, explanari, exsangues fieri."[l] In the words of Dr. Magendie, sixty years afterwards [m], "when the chest dilates, it inspires the blood of the cavæ, and successively that of the veins ending in them, much in the same way as it does the air into the trachea." Were Dr. Carson's account of expiration correct, as a vacuum would be

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mentaneo quasi vacuo, continuò in cor dextrum impellit sanguinis quantum facile capit pondus atmosphæræ." Quoted by Dr. M. Hall.

[l] l. c. lib. vi. sect. iv. p. 333. 1760.

[m] *Journal de Physiologie*, t. i. p. 136. 1821. For the same reason, if a tube is placed in the jugular vein, the air rushes into it during respiration with a noise, and the ill effects of air in the heart occur. (Magendie, l. c. p. 195.) And if a large vein is opened in surgical operations, and any thing prevents the sides from collapsing, the air may rush in and destroy life, as happened a few years ago at Paris. (l. c. p. 192. sqq.) This may be shown also, by inserting a tube, immersed in a coloured fluid, into a large vein, when the liquid will rise during inspiration, and stop or descend during expiration. (See Sir D. Barry, l. c. who conceives another source of vacuum to the pulmonary veins and venous sinuses, by the distraction of their parietes during inspiration, p. 29. 1826. And *Dissertation*, &c. p. 13. sq.) Still more recently, Sir D. Barry has applied the barometer to the chest of a pigeon, a viper, a common snake, and a frog, and found the mercury descend during inspiration. When connected with the exterior of the pericardium of an eel, the mercury became concave each time that the heart retired from the pericardium, so that its pulsations could be counted, and also at every effort of the animal to open its gill covers. *Sur l'Application du Baromètre, &c. Annales des Sciences Naturelles.* Avril, 1827.

threatening in the chest equally during expiration and inspiration, the shrinking of the lungs should occasion the blood to stream towards the heart as much during the one as the other, to fill up the vacuum. But this is not the fact, any more than, as we saw, that air rushes into the wounded pleura during expiration. The coincidence of the effect of inspiration on the venous blood, and, when the pleura is wounded, on the air, prevents us from supposing that inspiration affects the circulation merely by giving a free passage of blood through the lungs. "The great venous trunks of the head, neck, chest, abdomen, fore-extremities," says Haller, "swell *during expiration*, from the blood either being obstructed or retrograding, and at inspiration are emptied of it from its flowing freely to the heart."[n] Or, in the words of Magendie, "when the chest contracts, the blood is driven back into the cavæ by the pressure experienced by all the organs of the chest." That the blood does really retrograde during expiration, appears by an experiment of Magendie's, in which a hollow bougie was passed into the great veins as far as the cava, or auricle itself, and the blood flowed from its extremity during expiration.[o] This fact seems to show compression of the thoracic organs during expiration, and therefore is an additional argument that ordinary expiration is not the effect solely of the elastic and muscular shrinking of the lungs. Such, indeed, is the pressure of expiration, that the heart during it propels the blood more violently into the arteries, and even into the veins; and, on the other hand, less forcibly during inspiration.[p] A continuance in refrain-

[n] l. c. ibid. [o] *Journal de Physiologie*, t. i. p. 186. Paris, 1820.

[p] Bordeu, *Du Pouls*, p. 324. quoted by Haller; and Bichat, *Recherches Physiol.* p. 223. See Magendie for the veins, *Journal de Physiol.* t. i. p. 138., and Tulpius, *Obs. Med.* ii. 3. p. 106. In violent efforts the chest is still more compressed, whence the blood accumulates without the heart in the veins, and is driven more forcibly from the heart to all parts. These may be made after expiration or inspiration; but for a very violent effort we usually inspire first, to afford a better fixed point, and to continue the effort longer than would be possible after expiration. Respiration is generally suspended and the glottis closed; but if the effort is made after an inspiration, the glottis need not be closed, provided the air is allowed to leave the chest very slowly.

In myself, a deep inspiration, not followed in due time by an expiration, causes the pulse in a few seconds to become suddenly slow for a few seconds, falling as much as five and twenty beats per minute, and even double this, if it has just become rapid by a deep and prolonged expiration: but, as the breath continues to be held, which may be done much longer than inspiration can be refrained from ing to inspire after a violent expiration, of course almost suspends the circulation, by depriving the heart of blood [q], which is no longer drawn to the heart by inspiration, and has been squeezed out by expiration: a continuance in refraining to expire after a deep inspiration has the same effect, but more slowly. In both cases the blood is no longer drawn to the heart by inspiration, and does not experience those chemical changes in the lungs which are indispensable to its free passage through them; though, they being, in the former, filled with air, and empty in the latter, it can continue to pass through them much longer in the former.

And this leads me to observe, that the mere suspension of respiration impedes the circulation through the heart, by causing obstruction in the lungs; and that, consequently, inspiration, by giving free passage to the blood through those organs, will accelerate its course through the veins, independently of a vacuum; although the influence of the vacuum is shown by the effect of inspiration upon the contents of tubes inserted, not into the veins, but merely into the cavity of the pleura or pericardium. Whether respiration is suspended after an expiration or an inspiration, the effect is the same:—the blood accumulates in the lungs and right side of the heart, if the windpipe is tied, whether the lungs be empty or full at the time of the ligature; and therefore it is not merely the mechanical condition of the lungs that produces the obstruction in this case, as was once supposed, but the want of chemical changes.[r]

But for this consideration, the effects of the thoracic vacuum on the circulation might be overrated; and, indeed, that too high an estimate has been formed of it is very certain: for,

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after expiration, as there is a supply of air in the lungs in the former case, and not in the latter—(in the latter I can refrain for a quarter of a minute, and in the former for rather above a minute)—the pulse gradually resumes its former quickness; and, when the breath can be held no longer, evidently grows more and more rapid and weak. The effects of refraining from expiration are the same in me as of refraining from inspiration. Rapid respiration quickens the pulse, by drawing the blood more frequently to the heart; and, in my case, if very deep as well as rapid, the circulation through the head becomes so violent that vertigo occurs, and, between this and the rapidity of the pulse, I at length cannot count the latter.

[q] My own pulse, if a deep expiration is made, and inspiration refrained from, becomes rapid and excessively feeble, and more and more so till I can hold out no longer.

[r] See Haller, l. c. lib. vii. sect. iv. p. 253.

1. In the fœtus, and in animals which do not respire at all, or not by a thoracic vacuum, the vacua arising from the dilatation of the heart's cavities, and from its diminished bulk under contraction, only can occur.[s]

2. If we suspend respiration and prevent the influence of both sources of vacuum, the circulation continues till the want of chemical changes arrests it; and, if the vena cava, or any great vein, is obstructed so as to cut off connection with the heart, it becomes distended with blood[t] coming up towards the heart; and, if wounded between the ligature and the extremities, the blood flows, whatever the position of the animal, till death ensues.[u] In these cases no vacuum assists. If the pericardium is laid bare, so that no vacuum can occur, except that from the dilatation of the heart's cavities, and the trachea tied, the right ventricle swells enormously with the arriving blood[v],—a fact not to be explained by vacuum, not even by the heart's own vacuum. The influence of the left ventricle upon the course of the blood in the veins was also shown by Magendie, who firmly tied every part of a dog's leg, except the great artery and vein, and then tied the latter and wounded it below the ligature, when the blood was projected to some distance, and continued to be so, except when the artery was compressed; and, as long as the circulation continued, the stream from the vein was regulated at pleasure by compressing or liberating the artery.[x] If a turgid vein in the hand is compressed, it will not become empty above, as it should if suction from one or all of the three sources mentioned were considerable; and the jet of blood from an artery was found by Hales to be greater during a deep inspiration[y], (probably from the more abundant supply to the left side through the lungs), showing the action of the ventricle to be proportionably greater than the power of the thoracic vacuum at the moment of inspiration to oppose the discharge of blood from it. Still the effects of the vacuum are such as we have seen.

[s] On connecting the barometer with the interior of the pericardium of an eel, Sir D. Barry found the mercury move.

[t] Hunter, *On the Blood*, p. 75. sq. Haller had previously ascertained the same thing, and, while allowing the influence of a vacuum, urged it as a proof, that the vacuum was not efficient, but only auxiliary. *El. Physiol.* t. ii. p. 325.

[u] Mr. Spry, *Lancet.* Jan. 1827.

[v] Dr. David Williams, *Edinb. Med. and Surgical Journal*, 1823, p. 528.

[x] *Journal de Physiol.* t. i. p. 111.

[y] *Statical Essays*, vol. ii. p. 6.

The empty condition of the arteries after death has been ascribed by Dr. Carson to the thoracic vacuum. He states that, if an animal is destroyed by admitting air into each pleura, the arteries are found as turgid as the veins[z]; but the same results have not been obtained by others[a]; and I presume that the obstruction in the lungs from the want of chemical changes, gradually lessening the supply to the arteries, and producing accumulation in the veins, together with the superior contractile powers of the arteries, are, jointly, quite sufficient to explain the circumstance. The effect of the obstruction in the lungs, while the left ventricle continued to propel blood, was strikingly shown by Bichat, who produced enormous congestion of the lungs, liver, spleen, &c. by strangling animals slowly, and found much less if respiration was completely arrested at once, so that the left ventricle ceased to propel blood very soon after the obstruction in the lungs took place.[b] The greater the space into which the former blood can flow from the arteries, the less blood will they contain. Hence, if a ligature is passed round the cavæ, some quantity of blood is found in the arteries; if around the pulmonary artery, less; and, when the lungs have been kept distended after death by artificial inflation after opening the chest, so that all their vessels might be unfolded, the arteries have been found quite empty, though there was no thoracic vacuum[c], and though the effect of the left ventricle of the heart was destroyed by a ligature on the aorta.

Therefore, if Dr. Carson's experiments on this point are accurate, I should ascribe the turgidity of the arteries when the pleuræ were filled with air, and the lungs compressed, to the diminution; and when this was not done, the emptiness of the arteries, to the largeness, of the pulmonary space into which the blood could pass.

The influence of suction has been thought by Dr. Carson to assist in explaining absorption.[d]

Dr. Carson ascribes the effects experienced in elevated situations to the rarity of the atmosphere, by which it cannot compress the blood sufficiently to aid the return of this fluid towards the heart. Saussure[e] says, that when he was on the summit of the Alps he experienced extreme fatigue and loss of muscular power,

[z] *Med. Chir. Trans.* vol. xi.

[a] Dr. Fennel, *The Philadelphia Journal*, Nov. 1822.

[b] *Recherches Physiologiques*, p. 225. sq.

[c] Mr. Robert Hunter, *Edinburgh Journal*, Oct. 1824.

[d] l. c. p. 167.

[e] *Voyage dans les Alpes.*

and irresistible, rapid, and violent palpitation, and difficulty of breathing, all which soon ceased on his assuming the horizontal posture, in which, of course, the blood circulates more easily. His guide, a slim old man, was unaffected, and climbed with ease like a goat, and many unaccustomed to such elevations have been equally unaffected; for habit or a strong heart will render the influence of pressure but little necessary.

Gravity has been thought by Dr. Carson, as well as by older writers, materially to aid the circulation: — "By the stroke of the heart, a quantity of fluid is withdrawn from one end of the column, and by the synchronous vibration of the arteries an equal quantity is added to the other." "A perpetually repeated generation of motion must be produced through the different parts of the venous system by gravity, and this motion must be from the ends of the veins to the trunks."[f] "The simplest weight of a column of blood in any descending artery is sufficient to raise the blood through open capillaries to an equal height in the corresponding vein, according to the hydrostatical law, that fluids attain the same level in all communicating vessels."[g] Yet, in the horizontal posture, there can be no assistance from gravity, but the circulation proceeds perfectly well: and, indeed, gravity, on the whole, seems to impede the circulation; for, if the arms hang down for a length of time, or the legs are not rested horizontally, they ultimately swell. Nothing assists the heart more than a horizontal posture, as seen in syncope, in which the restoring agency is perfectly explicable by its mechanical aid to the heart, without reference to the brain.[h] The effects of posture are necessarily greater in tall persons. In the horizontal posture, the heart, having less to do, beats more slowly, and in very tall persons the pulse has been found 12 or 20 beats quicker in the upright posture.

The operation of exercise is very material. If an extremity is not exercised, its circulation always becomes languid, it resists external temperature with difficulty, and wastes; and, if gravity also co-operates by a vertical position, it swells; and exercise will prevent the congestive agency of a continued vertical position. Violent exercise causes proportionate violence of circulation. The action of muscles evidently operates by compression, and chiefly of the veins, as the coats of the arteries are so much stronger. The

[f] l. c. p. 138. sq.

[g] *Elements of Physics.* By N. Arnott, M.D. Lond. 1827. p. 500.

[h] See Bichat, l. c. p. 198. sqq.

blood can go but one way. The stream behind, and the valves in the veins of the extremities, determine the effects of the pressure to be in the course of the circulation. The compressed vessels are at once nearly emptied, and the instant that the pressure is alternately removed are again filled; and the momentary impediment during the compression is immaterial, on account of the innumerable venous anastomoses. The progress of the blood cannot but be accelerated. The dyspnœa that is felt arises from the force with which the blood drives through the lungs, and which renders frequent respiration necessary.

In the fœtus the case is analogous, although Dr. Carson has imagined it different, and thought it necessary to frame a little hypothesis to reconcile circumstances. The fœtal lungs, experiencing no atmospheric pressure, are contracted to the utmost, and the diaphragm, suffering no stimulus from the will on account of uneasy sensation arising from want of breath, is completely relaxed, and forced upwards to remove the vacuum; and the venous blood without the thorax must be drawn forcibly into the right auricle, preventing the vacuum which the discharges of blood from the left ventricle tend to produce. In the fœtus, moreover, the blood is propelled into the aorta by *both* ventricles, as Mr. John Bell remarks, and, therefore, the circulation less requires other assistance. The vacuum from the dilatation of the cavities of the heart occurs in the fœtus and all animals which have a heart: but, in those which have no such respiration as the human, there can be no assistance to the circulation by *thoracic* vacuum.

The ordinary cause of the first inspiration appears to be the novel impression of cool air upon the surface; for, if at any time we are suddenly exposed to a cold wind, or plunge into cold water, the diaphragm and intercostal muscles instantly contract, and a sudden *inspiration* takes place. The blood rushes into the expanded lungs, and, being afterwards obstructed when the inspiratory muscles cease to act, and the elastic lungs shrink, gives rise to an uneasy sensation, which is instinctively removed by another inspiration, and thus respiration afterwards continues through life. The fact of respiration commencing before the chord is tied, shows that neither congestion in the aorta, nor deficiency of chemical changes, is the cause of the first inspiration. If an animal is born under warm water, its respiration begins at the moment you choose to bring it up into the air. Buffon proved this by causing a bitch's delivery to take place in a tub of warm water, and allowing the pups to remain there for half an hour.

The power of excitement of the surface to cause inspiration has been shown by Beclard and others, who, on mechanically irritating fœtal kittens still enclosed in the membranes, found inspiratory efforts take place at each irritation.

"The alternate motion of the chest continues, during health and freedom from restraint, from the moment of birth till death. Its object is, that the lungs may be expanded to admit the air, and contracted to expel it, in perpetual alternation. This alternation occurs, in an adult at rest, about 14 times in a minute,—once to about five pulsations of the heart."[i]

"For man, in common with all warm-blooded animals, cannot long retain the inspired air, but is compelled to discharge it and take in a fresh supply of this pabulum of life, as it always has been denominated.[k] Common observation teaches, that, however pure may be the air entering the lungs, it instantly undergoes remarkable changes, by which it is contaminated and rendered unfit for another inspiration, unless it is renewed.[l]

The common quantity of air taken in at each inspiration is about 16·5 cubic inches; and the quantity remaining after death in the lungs of a stout adult man, about 100 cubic inches, according to Allen and Pepys. Dr. Bostock, agreeing with Dr. Menzies and many others, believes 40 cubic inches to be the average inspir-

[i] But this varies in different individuals, and in disease. When there is disease of the heart, with excitement, the proportion of the heart's action is greater than natural; and where of the lungs or pleura, the proportion is on the side of respiration. But the action of both the heart and respiratory organs is increased in the affections of either. I have at this moment a young female patient, in whom, through a nervous affection, I always find the respirations 98 and the pulse 104. My clinical clerk says he has found the respiration 106 and the pulse 104. The inspirations are shallow. She is in no danger. The quickest pulse I have ever felt has been 208, counted easily at the heart, though not at the wrist. In the two middle-aged men in whom I observed this, there was merely morbid irritability of the heart, and they walked about and ate like other people, though indisposed. One is now very well.

[k] "The antiquity of the notion that air is the *pabulum vitæ* is seen in the book *de Flatibus*, usually ascribed to Hippocrates. The author regards the aliment as threefold,—victuals, drink, and air; but the latter he calls *vital*, because we cannot, for a moment, dispense with a supply of it without danger to life."

[l] "Consult Harvey's Dispute upon the necessary renovation of the aërial *succus alibilis*, with the celebrated Astronomical Professor, J. Greaves, in the latter's *Description of the Pyramids in Egypt*, p. 101. sq. Lond. 1646. 8vo.

Also the popular Edm. Halley's immortal *Discourse concerning the Means of furnishing Air at the Bottom of the Sea in any ordinary Depths.*—*Phil. Trans.* vol. xxix. No. 349. p. 492. sq."

ation, and thinks that 160 or 170 remain in the lungs after ordinary expiration [m]; for these organs are never emptied by expiration.

"It may be asked, what are the changes which the air experiences during inspiration, and which consist not in the loss of elasticity, as was formerly imagined, but in the decomposition of its elements. [n] For the atmospheric air which we breathe, is a peculiar mixture of constituents, differing very much in their nature from each other; and, not to mention heterogeneous matters, such as odorous effluvia, various other besides aqueous exhalations, and innumerable other substances, which are generally present, is always impregnated with aqueous vapour, electric and magnetic matter, and generally with carbonic acid gas; and is itself composed of unequal parts of two aëriform fluids, viz. 79 of azotic gas, and 21 of oxygen gas in 100.

"In the first place, we know for certain, that, at every inspiration (the fulness of which varies infinitely in different persons of the same age, breathing placidly [o]), besides the quantity of azotic gas being somewhat diminished [p], the oxygen gas is in a great measure converted into carbonic acid gas or fixed air; so that the air of expiration, if collected, instantly extinguishes flame and live coals, precipitates lime from lime-water, and is specifically heavier than atmospheric air, and rendered unfit for inspiration [q]; it also contains much aqueous vapour, which is condensed in a visible form by a temperature not exceeding 60° of Fahr." [r] The ordinary quantity of aqueous vapour emitted by

[m] *An Elementary System of Physiology*, vol. ii. p. 24. sq. Dr. Thomson thinks the estimate of Menzies most correct. *System of Chemistry*, vol. iv.

[n] "Fr. Stromeyer, *Grundriss der theoretischen Chemie*, P. ii. p. 619.

[o] "Consult, v. c. Abildgaard, *Nordischen Archiv. für Naturkunde*, &c. t. i. P. i. and ii."

[p] "Consult, besides, Priestley and others, especially C. H. Peaff, ib. t. iv. P. ii."

[q] "To discover how frequently an animal could breathe the same portion of the different kinds of air that we have mentioned, I took three dogs equal in size and strength, and to the trachea of the first, by means of a tube, I tied a bladder, containing about 20 cubic inches of *oxygen* gas. He died in 40 minutes.

For the second, the bladder was filled with *atmospheric* air. He died in six minutes.

For the third, I employed the carbonised air last expired by the second dog. He died in four minutes.

The air of the bladder, upon subsequent examination, gave the common signs of carbonic acid gas.

The instruments which I employed are described and illustrated by a plate in the *Medic. Biblioth.* vol. i. p. 174. sq. tab. 1."

[r] "J. A. De Luc, *Idées sur la Météorologie*, tom. ii. pp. 67. 229."

the lungs, trachea, throat, and mouth, may be about 20 oz. in 24 hours.[s] It is probably derived from the chyle, and by the separation of so much water, the *weak* and delicate albumen of the chyle is converted into the *strong* and perfect albumen of the blood.[t]

"There is, consequently, no doubt that the carbonic acid of the expired air is derived from the venous blood carried to the lungs from the right side of the heart.[u] But it has been of late disputed, whether the inspired oxygen goes wholly to form carbonic acid in the bronchial cells[v], or whether it is in part united with the arterial blood and distributed through the arterial system.[x] Many weighty arguments seem to favour the latter opinion, as well as the phenomena of both kinds of blood in the living body[y], compared with the changes which this fluid experiences when exposed to these two kinds of air."

After much uncertainty, it was thought ascertained by the experiments of Messrs. Allen and Pepys that no oxygen is absorbed in ordinary respiration, but that what disappears goes entirely to unite with the carbon of the blood and produce carbonic acid, the latter being exactly equal in bulk to the oxygen which disappears, — about 27½ cubic inches per minute, or 39,534 in twenty-four hours, according to the experiments of these gentlemen, — a quantity containing about 11 oz. troy of solid carbon, more than equal to the carbon contained in 6 lbs. of beef[z], and, perhaps, about double the average result of most other experiments.

[s] See Hales. See also chapter on Perspiration.

[t] Dr. Prout, l. c. p. 525.

[u] "Rob. Menzies, *De Respiratione*. Edinb. 1790. 8vo.
H. G. Rouppe, on the same subject. Lugd. Batav. 1791. 4to.
J. Bostock, *Versuch über das Athemholen. übers. von* A. F. Nolde. Erf. 1809. 8vo."

[v] "W. Allen and W. H. Pepys, *Phil. Trans.* 1808, p. 249. and 1809, p. 404. But how various the quantity of carbonic acid gas expired is, at different times of the day, and under different circumstances, is shown by the experiments of W. Prout, in Thomson's *Annals of Philosophy*, vol. ii. p. 328."

[x] "Nasse, in J. F. Meckel's *Archiv. für die Physiol.* vol. ii. p. 200.
And G. Wedmeyer, *Physiologische Untersuchungen über das Nervensystem und die Respiration*. Hanov. 1817. 8vo. p. 175."

[y] "J. Andr. Scherer, *Beweis, dass* J. Mayow *vor* 100 *Jahren den Grund zur antiphlogistischen Chemie und Physiologie gelegt hat*, p. 104.
Edm. Goodwyn, *Connexion of Life with Respiration*. Lond. 1788. 8vo.
J. Hunter, *On the Blood*, p. 68.
J. A. Albers, *Beyträgen zur Anat. und Physiol. der Thiere*, P. 1. p. 108."

[z] Dr. Prout, l. c. p. 526.

But Dr. Edwards has since shown that, however correct were these results, it was erroneous to generalise from them; that more *oxygen* is continually consumed by brutes than goes to the formation of carbonic acid; and that this excess varies from above $\frac{1}{3}$ of the volume of the latter to almost nothing.[a] The variation depends not only upon the species, but upon the developement relative to the age, and upon individual differences in adults.

He therefore finds that the bulk of the air is not unaffected by respiration, but that generally a diminution takes place. Dr. Le Gallois[b] and Dr. Delaroche[c] also found that oxygen disappeared in greater quantity than carbonic acid was formed.

Allen and Pepys observed that, if the same air was breathed repeatedly, some oxygen was absorbed and some azote discharged, and that, if nearly pure oxygen was employed in the case of guinea-pigs, carbonic acid was produced and a portion of the oxygen replaced by azote, this portion decreasing, however, as the experiment proceeded.

Dr. Edwards ascertained that respiration causes sometimes an increase of *azote*, sometimes a diminution, and sometimes no important difference in its quantity. He thinks that it is always being absorbed and discharged, and that the proportion of these processes differs under different circumstances. Its discharge exceeds at all times in very young animals, as seen in guinea-pigs; and in spring and summer; while its absorption exceeds in autumn and winter, as far as his experiments upon adult sparrows and yellow-hammers go; though occasional exceptions occurred from unappreciated circumstances, powerful enough to overbalance the effect of season.[d] The difference in the proportion of the inspired and expired azote never equalled the greatest differences observed between the oxygen which disappeared and the carbonic acid formed. Cold-blooded quadrupeds were shown by Spallanzani[e] to absorb azote, and fish by Humboldt and Provençal.[f] Sir Humphry Davy had already ascertained the absorption of azote in his own person.

Dr. Edwards's reasons for believing azote to be constantly both absorbed and discharged are :—

[a] *De l'Influence des Agens Physiques sur la Vie.* Paris, 1824. p. 410. sqq.

[b] *Annales de Chimie et Physique*, t. iv. p. 115. sq.

[c] *Journal de Physique*, t. 77.

[d] l. c. p. 420. sqq. 461. sqq.

[e] *Mémoires sur la Respiration*, pp. 184. 258.

[f] *Mémoires d'Arcueil*, t. ii.

1. That if an animal is made to breathe oxygen mixed with $\frac{1}{20}$ of azote, azote is discharged in abundance, as was found by Allen and Pepys, so that, when there is little or no azote to be absorbed, its exhalation at once shows itself; and we may conclude that in common respiration its exhalation may be as great, but not observable, because nearly an equal quantity is absorbed:

2. When a mixture of oxygen and hydrogen was employed by those chemists, and pure hydrogen by Dr. Edwards, not only was a large quantity (much exceeding the bulk of the animal) given out, but a considerable quantity of *hydrogen* was absorbed, in Dr. Edwards's experiment equal to the azote given out [g], proving that exhalation and absorption can proceed together: and he asks why, if hydrogen is absorbed, not much more so azote, which is more fit for respiration and the support of life? and concludes that its absorption may be as great in common respiration, but not observable because a nearly equal quantity is discharged. [h]

Carbonic acid itself is shown by Spallanzani and Dr. Edwards [i] to be exhaled from the lungs independently of the operation of oxygen; when snails, frogs, fish, or very young kittens, are immersed in hydrogen.

It is satisfactory that Messrs. Allen and Pepys were induced, without any knowledge of Dr. Edwards's researches, to repeat their enquiries, and their results no longer disagree with those of Dr. Edwards. On making birds breathe in atmospheric air, they still found the loss of oxygen equal to the addition of carbonic acid, and the nitrogen unchanged; if in air with an excess of oxygen, a quantity was absorbed beyond what was replaced by carbonic acid, and in its room appeared an equal quantity of nitrogen; if in a mixture of oxygen, hydrogen, and nitrogen, the oxygen being in the same proportion as in atmospheric air, there was no loss of oxygen, but of hydrogen, which was exactly replaced by nitrogen. [k]

Mr. Ellis [l] contends that the carbon is excreted by the pulmonary vessels, and unites with the oxygen externally, and Dr. Prout thought this opinion corroborated by the fact [m], —that, when phosphorus dissolved in oil is injected into the blood-vessels,

[g] l. c. p. 462.

[h] l. c. 429. sqq.

[i] l. c. p. 437. sqq.

[k] *Phil. Trans.* 1829.

[l] *An Enquiry into the Changes induced in Atmospheric Air.* 1807. *Further Enquiries, &c.* 1816

[m] Dr. Orfila, *Toxicologie Générale,* t. i. p. 531. sq. Dr. Magendie had previously found the same result in injecting the solution into the pleura.—*Mémoire sur la Transpiration,* p. 19.

vapours of phosphorous acid stream from the mouth and nostrils, — what would hardly have occurred if the acid had been formed in the vessels, as it would probably have remained in solution in the blood, not being volatile. The phosphorus was probably excreted from the vessels in minute subdivision, and united with the oxygen of the atmosphere upon coming in contact with it, producing phosphorous acid; and the same may be imagined respecting the carbonic.[n] There can be no reason to adopt this hypothesis on account of the supposed difficulty of the air and blood acting upon each other through the vessels, because we saw in p. 149. that they do so, through moistened bladder, out of the body.

The well-known secretion and absorption of air in membranes, shown by the existence of air in the air-bladder of fish, the sudden formation of air in the alimentary canal in disease, the absorption of air in emphysema, and the occurrence of emphysema without injury of the lungs[o]; the separation of azote and carbonic acid from the lungs when hydrogen is breathed, and the absorption of azote and of oxygen, in the experiments of Dr. Edwards, prove the possibility of the oxygen being absorbed, and the carbonic acid secreted.

Lavoisier at one time, and La Grange and Hassenfratz long ago, contended that the carbonic acid is generated in the circulation, and given off in the lungs, and the oxygen absorbed.

Dr. Edwards also argues that, since so much carbonic acid is given out from the blood in the respiration of pure hydrogen, and that, since the quantity given out in hydrogen is as great as is observed in common air, there can be no reason to doubt that, in common air, the carbonic acid proceeds from the same source as in hydrogen, *viz.* — passes from the blood; more especially as carbonic acid exists largely in the blood: and that the oxygen, therefore, must pass into the blood. These arguments are, in my mind, irresistible. But whether mere carbon leaves the blood and forms carbonic acid with the oxygen externally to the vessels, as in the former theory, or the oxygen unites with, and the carbonic acid separates from, the blood, as in the latter, much of the affair would appear chemical, — neither all the carbon nor all the carbonic acid gas to be *secreted;* because it has long been known,

[n] Dr. Thomson's *Annals of Philosophy.* 1819.

[o] See a case related by Dr. Baillie, in the *Transactions of a Society for the Improvement of Medical and Chemical Knowledge*, vol. i.

that, when venous blood is exposed to oxygen out of the body, even although covered by a moistened membrane, it becomes florid, and oxygen disappears and is replaced by carbonic acid.

Since the publication of Dr. Edwards's work, numerous facts have been ascertained, which cause his opinions on these points to be generally received, by proving the possibility of the transfer of oxygen to the blood, and of carbonic acid to the air, even on chemical principles. My friend Dr. Stevens discovered that oxygen and carbonic acid attract each other; so that, if carbonic acid is placed at the lower part of a tube, and oxygen above, the acid, though heavier, will ascend and the oxygen descend. Nay, if a vessel filled with carbonic acid be completely closed with bladder, the acid will escape and the bladder be forced in; while, if it be filled with air and placed in carbonic acid, the latter will pass through and distend the bladder till it nearly bursts. The tendency to diffusion is universally as the square root of the specific gravity. The subject has been prosecuted by Drs. Mitchel and Faust [p]; and they have ascertained that both living and dead membranes, and even caoutchouc,

[p] *American Journ. of the Medical Sciences,* No. xiii. 1830. They do not mention Dr. Stevens's name, but he had made his observations in the West Indies in 1827 and committed them to paper, and shewn them in England in 1828, in France in 1829, and in America in the summer of 1830, when he mentioned them to the very editor of the *Journal of Medical Sciences,* who took part in Dr. Mitchel's experiments, which were soon afterwards begun and published before the end of the year. In 1833, also, M. Saigay published (in the *Annales des Sc. d'Observat.* t. iii. p.452.) an explanation of the interchange of gases through fluids and porous substances; that each gas maintains an equilibrium outside and inside; so that, when there is less without, it passes forth; and, when more without, it passes in. In this way M. Raspail conceives that the appearance and disappearance of all the various gases in respiration, under different circumstances, may be accounted for. (l. c. p. 258.) There must be, however, a relation between different gases, or nitrogen would be exchanged, as well as oxygen, for carbonic acid, in ordinary respiration.

M. Dutrochet stated that, if a dense fluid is enclosed in an animal membrane, it attracts a thin fluid placed around the exterior. The passage of the external fluid he called endosmose. If the dense fluid is placed externally, and the thin inside, then the thin fluid passes outwards. This passage he termed exosmose. M. Raspail soon adduced exceptions to this, and showed that the phenomena were merely those of ordinary imbibition: that, if the fluid on one side was of a kind to pass through membrane, and the fluid on the other was not, and the two were of a kind to unite, then the one fluid of course soaked into the membrane and, having soaked into it, united with the other fluid, as soon as the other side of the membrane was reached; and more followed in its place. (l. c .p. 80* sqq.)

as well as water and other liquids, are freely permeable to the different gases. They have also discovered that gases pass through with different rapidity: carbonic acid, for instance, very quickly; nitrogen, very slowly: whence the different state of the bladder just mentioned, accordingly as carbonic acid is introduced into the vessel in common air, or common air introduced into the vessel in carbonic acid. The appearance of carbonic acid outside a bladder tied over a vessel of venous blood or water impregnated with carbonic acid, and the disappearance at the same time of a portion of the oxygen outside the bladder tied over venous blood, is no less than what occurs to the blood of the lungs in respiration, and the blood in both cases becomes florid.

The lungs thus seem to serve the purpose, in this respect, of merely exposing an immense surface of blood to the air. Blood could not be so near the air on the exterior of the body without constant injury of the innumerable delicate vessels, nor could the vascular surface be preserved in a moist state, which is necessary to the permeability of those vessels. Besides which, succession of air to each point could not be secured. The Creator has therefore wonderfully provided an immense surface within, of the very finest texture, secure from external injury and supplied with constant moisture, and continually exposed not only to the external air, but to successive draughts of it.

The changes of the blood in respiration are therefore purely chemical, and just the same as occur to venous blood out of the body, in contact with air or separated from it by merely a moistened bladder, and are detailed at page 149. Oxygen unites with the blood; carbonic acid proportionately escapes. The blood, thus liberated from the cause of its blackness, re-acquires the florid hue occasioned by its salts, but which are not naturally in sufficient quantity to brighten it when much carbonic acid is present.

Dr. Crawford observed that less carbonic acid was evolved in proportion to the height of the temperature [q]; Dr. Jurine, that more was evolved when the circulation was quickened, — during the hot stage of fever, digestion, or exercise, and less in the cold stage [r]; and his results were confirmed by Lavoisier and

[q] *On Animal Heat*, p. 387.

[r] *Encyclopédie Méthodique*, t. i. p. 494. Dr. Prout also observed this effect of exercise before fatigue occurred.

Seguin.[s] Dr. Edwards has found less evolved in summer than in winter.[t]

Dr. Prout and Dr. Fyfe[u] have found the quantity of carbonic acid gas diminished by mercury, nitric acid, vegetable diet, tea, substances containing alcohol, depressing passions, long fasting, and fatigue, and probably by sleep. Dr. Prout found that it undergoes in himself an increase from daybreak till noon, and a decrease from noon till sunset, remaining at the minimum till daybreak. In the experiments of Allen and Pepys, the formation of carbonic acid gas slackened when the guinea-pigs fell asleep. Dr. Prout also observed that an increase or decrease from the maximum or minimum was followed by a proportional decrease or increase during a diurnal period. It would appear, also, that less is formed in infancy, and more as the adult age is approached, in brutes.[v]

When the air is not changed, death in general occurs long before all the oxygen is consumed, through the carbonic acid which is formed; but bees, some worms and mollusca, completely deoxidize it.[x] Snails will live in air in which a bird has died.

Lavoisier removed the carbonic acid by potash as quickly as it was produced, and found that a guinea-pig could live in air containing but 6·66 per cent. of oxygen, and with still less became only drowsy.[y]

[s] *Mémoires de l'Académie des Sciences.* 1789. p. 575.

[t] l. c. p. 200. sqq.

[u] l. c. *Dissert. Inaugur. &c.* Edin. 1814. The smallest quantity yet observed was in a diabetic patient of mine, taking very large doses of opium and nux vomica. *Numerous Cases, illustrative of the Efficacy of the Hydrocyanic or Prussic Acid in Affections of the Stomach, with a Report upon its Powers in Pectoral and other Diseases, in which it has been already recommended, and some Facts respecting the Necessity of varying the Doses of Medicines according to circumstances, and the Use of Opium in Diabetes.* By John Elliotson, M.D. &c. p. 99.

[v] Boyle, *Works*, vol. iii. p. 360. Edwards, l. c. p. 189. sqq.

[x] Vauquelin, *Annales de Chimie*, tom. xii. p. 278. Spallanzani, *Mém. sur la Respiration*, p. 63.

[y] Some assert that the respiration of pure oxygen excites violently, others gently, others not at all; some, that more oxygen is consumed than in common, some no more. Mr. Broughton, in a paper read a few years ago in the Royal Society, but not published, found, as Allen and Pepys had previously, that oxygen, when respired pure, excites and causes all the visible blood to be florid; but the animal gradually becomes exhausted, falls in temperature, and at length dies, while the oxygen is still pure enough to produce the same effects on a second and third animal. The blood quickly coagulates after the respiration of pure oxygen. Pure

Dr. Edwards advances, contrary to Morozzo[z], that every warm-blooded animal perishes instantly[a] when placed in the air in which another has died through want of renovation, and that all of the same class among them deoxidize it equally, though in different times. This time will occasionally differ $\frac{1}{3}$, notwithstanding the size of the body and the movements of the chest be equal in them, and the carbonic acid removed as quickly as formed. The young deoxidize it more slowly than adults; and the young, if quite deprived of air, die later than adults.[b] Indeed, Buffon found, and Dr. Le Gallois and Dr. Edwards have confirmed his discovery, that new-born animals of many species, as dogs and rabbits, will live a long time without air, even after they have been allowed to respire. This period lessens as the animal's temperature rises with age; and in those whose temperature is at birth high, as guinea-pigs, it is very short.[c] They live longer than adults also in a limited quantity of air.[d] Amphibious animals likewise live long without air.[e]

Persons have been said to be able, by habit, to live without air a considerable time. Death generally occurs at the latest in one or two minutes, when respiration is suspended; but by habit some few divers of the swimming school at Paris can remain under water three minutes.[f] If the system is in an extraordinary nerv-

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hydrogen and azote appear to destroy by the mere exclusion of oxygen; carbonic acid by poisoning, but, if not diluted with rather more than double its bulk of common air, it will not pass the glottis. Sulphuretted hydrogen instantly poisons: carbonic oxide is fatal less quickly, and the venous blood accumulates within, and the animals are very hot. Nitrous oxide intoxicates quickly, briefly, and without consequent exhaustion, and appears to be absorbed by the blood (see Sir Humphry Davy's *Researches*, &c.); but it destroys at length, and sooner than pure oxygen, according to Mr. Broughton: the blood is thin, and continues fluid. Drowning destroys life only by the exclusion of air; and, as the glottis closes, little or no water — nothing often but frothy mucus — is found in the air-passages. Yet Professor Meyer asserts, that he has seen the fluid in which the animal was drowned, generally, in the lungs, in his experiments.

[z] *Journal de Physique*, t. xxv. p. 102. sqq. One reason that an animal will live in air in which another has died, is, that it comes fresh and strong into it, and therefore resists the poison better than its enfeebled predecessor.

[a] *Mémoires de l'Académie des Sciences*. 1789. p. 573.

[b] l. c. p. 184. sqq.

[c] Edwards, l. c. p. 191. sqq.

[d] l. c. p. 513. sqq.

[e] Sir Anth. Carlisle, *Phil. Trans.* 1805.

[f] Edwards, l. c. p. 269. Mr. Brydone (*Tour through Sicily and Malta*) fre-

ous state of insensibility, the absence of air, like the absence of food or the administration of strong agents, may be borne for a very long time. Even fainting renders submersion less dangerous.

Venous blood is not calculated for life. When it was injected into the carotids, Bichat found that the brain became affected, as if poisoned, and death gradually ensued; and, when it circulated through the coronary arteries of the heart,—the action of which organ will continue though its left cavities are supplied with venous blood,—the heart's motion ceased, and the functions of each organ were impeded, and at length ceased, when venous blood circulated through its arteries.[g] When death occurs by impediment to the functions of the lungs, the heart loses its irritability by its substance becoming penetrated with venous blood, and ceases to propel the blood of its cavities; and the brain, becoming powerless from the same cause, ceases both to perceive uneasiness in the lungs from the want of fresh air, and to be able to will inspiration. If the death of the body arise

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quently saw divers remain, in the Bay of Naples, under water for three minutes. In Percival's *History of Ceylon*, they are said sometimes to remain five minutes under water.

Some very grand instances of exaggeration on this subject will be found in an amusing and useful book, entitled *The Uncertainty of the Signs of Death.* M. D'Egly, Member of the Royal Society of Inscriptions, declares that he was engaged to a dinner for which the fish was to be provided by a Swiss diver, who got his living by plunging into the water and pulling the fish out of their holes. The dinner hour arrived, but no fish. Drags were employed, and the diver's body found. The curate wished to bury it immediately, as it had been nine hours under water, but M. D'Egly determined on attempting resuscitation, and succeeded in three quarters of an hour. The Rev. Mr. Derham, in his *Physico-Theology*, is more credulous than the Curé; he quotes Pechlin for the case of a man pensioned by the queen for having joined his fellow-creatures again, after remaining upright under water, his feet sticking in the muddy bottom, for sixteen hours, at Tronningholm. Yet this is nothing; for Mr. Tilesius, the keeper of the royal library, has written an account of a woman whom he saw alive and well, after being three days under water. And this is nothing; for Mr. Burmann declares he heard a funeral sermon at Boness in Lithovia, upon an old man of seventy, who, the preacher protested, had fallen into the water when sixteen years old, and remained under it for seven weeks. Mr. Brydone was told that one diver, called Calas, but nicknamed Pesce, could live several days in the sea; and Kircher asserts, that this aquatic person could walk under water from Sicily to Italy.

[g] Bichat, *Recherches Physiologiques*, p. ii. art. 6, 7, 8.

from the brain, it is by the brain being unable to continue respiration.

Still the circulation of venous blood excites in some degree for a time, and is better than no circulation; for Dr. Edwards placed some frogs, toads, and salamanders with their hearts entire, and others deprived of their hearts, in water deprived of air. Those with hearts survived the longest, occasionally twenty hours longer than the others.[h] It is worth remembering, as Dr. Stevens has pointed out, that blood may be black from the presence of carbonic acid, &c. or from the absence of saline matter.

Venous blood both abounds in carbonic acid and is deficient in oxygen. The state of combination of the oxygen abounding in arterial blood, and of the carbonic acid abounding in the venous, are unknown. As the blood is florid until it reaches the minutest vessels, we presume that in them the oxygen disappears, and the carbonic acid is produced. The oxygen is thought to meet with carbon there, and with it form the carbonic acid. Dr. Prout conceives that the carbon is derived from the albumen, when albuminous matters are converted into gelatine. This substance, which is not found in the blood nor in any glandular secretion, enters into the structure of every part, and especially of the skin, which is little else. Now this contains three or four per cent. less carbon than albumen. In nutrition, therefore, albuminous substances very extensively support a reducing process, lose their carbon to become gelatinous, and as this process must occur in the minutest vessels, their blood is charged with carbon, which, however, instantly finds oxygen (probably in solution in the water of the blood), and unites with it into carbonic acid.[i] It is thus that respiration assists assimilation, and not by discharging carbon from the chyle, as many have imagined. They forget that more carbonic acid is not found after every meal, nor less during fasting, till this proceeds to the length of debility: and that many animals sleep after feeding, yet in sleep less is produced.

Some suppose that respiration is very instrumental in preventing the putrefaction of the living body; and this by carrying off its carbon, — the substance which, in the spontaneous decomposition of animals, is the first rejected, and unites with the oxygen of the atmosphere; and, indeed, Spallanzani found, that the dead

[h] l. c. P. 1. c. i. sect. 2.

[i] *Bridgewater Treatise*, pp. 519. 524. sq. 535. sq.

bodies of animals deoxidated the air after death, and often as much as during life, before decomposition was perceptible.[k] He says also, that torpid animals, whose respiration had entirely ceased, also carbonated it. As the latter fact cannot be ascribed to the separation of carbon in the lungs, nor to the mere chemical changes of decomposition, it probably arises from the functions of the skin.

The delicate surface of the lungs, and, indeed, of the whole air-passages, is a great source of absorption from without, as well as of impressions from gaseous and imponderable substances. Many poisons affect the system by its means. It is also a great organ of elimination. Camphor, phosphorus, ether, diluted alcohol, gases, and various odorous substances, when introduced into the system, escape in a great measure by the lungs: whence they are perceived in the breath, and, perhaps for some time, long after they have left the stomach. Dr. G. Breschet and Dr. Milne Edwards, conceiving that in the dilatation of the lungs by inspiration, the enlarged space would cause not only the air to rush in, but the exhalation from the surface of the air-cells and pleura to increase and exceed that from other parts, have made several experiments which prove this to be the case. On injecting a *small* quantity of oil of turpentine into the crural vein, the breath instantly smelt strongly of it, and the pleura on being cut open did the same; while no odour of it arose on exposing the peritonæum. If a larger quantity was employed, it impregnated every part. If, instead of natural respiration, artificial was instituted, in which the air does not enter the lungs by the formation of a vacuum on the expansion of the chest, but is forced into them and itself expands the chest, no more exhalation of odorous substances took place from the lungs than from other parts; and, indeed, if a cupping-glass was applied over another denuded part, the odorous substance was given out there, while the lungs afforded no sign of it.[l]

"The perpetual change of elements occurring in respiration after birth, we shall show to be very differently accomplished in the fœtus, viz. by means of the connection of the gravid uterus with the placenta.

"But, when the child is born and capable of volition, the congestion of blood that takes place in the aorta, from the obstruction in the umbilical arteries; the danger of suffocation from

[k] *Mém. sur la Respiration.* See Dr. Bostock, l. c. vol. ii. p. 184. sqq.

[l] *Recherches Expérimentales sur l'Exhalation Pulmonaire.* Paris, 1826.

the cessation of those changes of the blood, in regard to oxygen and carbon, hitherto produced in the uterine placenta; the novel impression of that element into which the child, hitherto an aquatic being, is conveyed; the cooler temperature to which it is now exposed; and the many new stimuli which are now applied, seem to induce new motions in the body, especially the dilatation of the chest and the first inspiration.

"The lungs, being for the first time dilated by inspiration, open a new channel to the blood, so that, being obstructed in the umbilical arteries, it is derived to the chest.

"Since the inspired air becomes hurtful and unpleasant to the lungs by the decomposition which it experiences, I should ascribe to the most simple corrective powers of nature, the subsequent motion by which the poisonous mephitis, as it may be called, is expelled and exchanged for a fresh supply.

"The consideration of all these circumstances, especially if the importance of respiration to circulation, demonstrated by the well-known experiment of Hooke [m], be remembered, will, in my opinion, explain the celebrated *problem* of Harvey [n], better [o] than most other attempts of physiologists.[p]

[m] "It has the epithet Hookian, because it was most varied by Rob. Hooke. See Th. Sprat, *History of the Royal Society*. Lond. 1667. 4to. p. 232. But it was before instituted by Vesalius, and very much praised for its beauty. *De c. h. Fabrica*, p. 284."

The experiment consisted in laying the lungs completely bare, and reviving the animal by artificial respiration. Hooke varied it by pricking the surface of the lungs, and forcing a continued stream of air through them.

[n] "Wm. Harvey, *De circulat. sanguin. ad* J. Riolan. p. 258. Glasgov. 1751. 12mo."

These are the words of Harvey: — "It would appear that the use of expiration is to purify and ventilate the blood, by separating from it these noxious and fuliginous vapours." We must not, however, forget the words of Servetus, seventy years before, and already quoted at p. 195. — *expiratione fuligine expurgatur.*

"And especially his *Exerc. de gener. Animalium.* p. 263. Lond. 1651. 4to."

[o] "See Theod. C. Aug. Roose, *über das Ersticken neugeborner Kinder,* in his *Physiologisch. Untersuchungen.* Brunsw. 1796. 8vo.

J. D. Herholdt, *De vita, imprimis fœtus humani, ejusque morte sub partu.* Havn. 1802. 8vo."

[p] "Consult, for example, Petr. J. Daoustene, *De Respiratione.* Lugd. 1743. 4to. p. 54. sqq.

Rob. Whytt, *On the Vital and other Involuntary Motions of Animals,* p. 222. Edinb. 1751. 8vo."

Fish and *crustacea* purify their blood by the air contained in the water which they draw over their gills. They perish if the water is deprived of air; and in this case, as well as when the water is aërated but limited in quantity, and whether it is exposed to the air or in close vessels, they perish sooner as the temperature is higher. (Dr. Edwards, l. c. P. ii. ch. 2.) And the younger and smaller they are, when there is too little air in the water, the more they come to breathe at the surface, and the sooner die if prevented. (p. 118.) Fish die in the air by drying and wasting. (p. 126.) The *syren lacertina* and *proteus anguina* have both gills and lungs. *Insects* have no lungs, but openings on the surface of the body leading to air-vessels which are distributed in the interior. Dr. M. Hall has shown that, in the lungs of at least the toad, frog, and salamander, the blood-vessels subdivide into capillaries suddenly, so as to subdivide as much blood as possible, and cause it to present the largest possible surface. (l. c. p. 36. sqq.) All the experiments of naturalists made it appear that no animal could live without oxygen, but M. Biot has asserted that what are called *blaps* and *tenebrions* remain in as good a vacuum as can be formed for any length of time without apparent inconvenience. Animals found in many parts of the bodies of others can hardly be thought to have access to gaseous oxygen. In regard to the frequency of respiration in cold-blooded animals, Dr. Stevens incidentally mentions that he observed it no more than three or four times in a minute in an alligator, which he once held in his hand, and in which it was probably quick from the animal being young and agitated. (l. c. p. 35.)

In the light, vegetables produce changes in the air opposite to those produced by animals. They decompose carbonic acid, retain the carbon, and leave the oxygen. It is the green substance of *the living* leaf which effects the decomposition. In the dark, the leaves absorb oxygen; a tendency which, indeed, the flowers, roots, and other parts, always have. This oxygen unites with the carbon of the sap; and, although some of the carbonic acid formed is said to be exhaled, the greater portion combines with the fluids of the sap, and parts with its oxygen again in the leaves when daylight comes. Carbon obtained in the state in which it exists at the moment of its separation from carbonic acid appears the object. While animals, therefore, increase the carbonic acid of the atmosphere and lessen its oxygen, vegetables increase its oxygen and lessen its carbonic acid, at least during the light; and the functions of vegetables are the most active at that period of the year when the days are much longer than the nights.

CHAP. XIII.

ANIMAL HEAT.

"MAN, other mammalia, and birds, are distinguished from the rest of animals by the natural temperature[a] of their bodies greatly exceeding that of the medium in which they are accustomed to exist. Man is again distinguished from these classes of animals by possessing a much lower temperature than they; so that in this climate it is about 96° of Fahr., while in them, and especially in birds, it is considerably higher."[b]

But all animals, as far as can be ascertained, and even vegetables, have a tendency to preserve a temperature more or less distinct from that of the surrounding medium; yet the difference among them in this respect is so great, that they have been divided into warm and cold-blooded. To the former belong the more complicated, those whose pulmonary apparatus is most elaborate, — man and mammiferous quadrupeds and birds: to the second, oviparous quadrupeds, fish, and most of the invertebrate. Birds have the highest temperature, 107° to 110°; mammiferous quadrupeds, 100° to 101°; man, 96° to 98½°. There is some variety, not only in individuals, but according to age, season, and climate. It is less in the young, according to Dr. Edwards and Despretz[c]: the former states the human temperature in infancy to be 94¼°; the latter asserts, that, while in birds it is 105° in winter, it is nearly 111° in summer, gradually increasing in spring and decreasing in autumn. In the high temperature to which we

[a] "W. B. Johnson, *History of Animal Chemistry*, vol. iii. p. 79."

[b] "The torpid state of some animals, during winter, is of course an exception to this. During it most of the functions cease or languish considerably, and the animal heat is reduced nearly to coolness. This well-known circumstance prevents me from acceding to the opinion of the very acute J. Hunter, — that the animals which we call warm-blooded should rather be called animals of a permanent heat under all temperatures. *On the Blood*, p. 15."

[c] *De l'Influence des Agens Physiques. Edinburgh Journal of Science*, vol. iv. p. 185. J. Hunter states that the temperature of the ass is one degree higher in the evening than the morning. - *On the Blood*, p. 298.

shall see Dr. Fordyce and his friends were exposed, the temperature of the body rose two or three degrees, and Dr. Delaroche, in a vapour-bath at near 120°, found the heat under his tongue increased about five degrees at the end of seventeen minutes.[d] In sparrows and yellow-hammers, Dr. Edwards found it five or six degrees higher in summer than in winter; and Dr. Davy one or two degrees higher in Ceylon than in England.[e] In disease it will fall, and on the other hand rise; in fever it has been noted at 107°, in tetanus at 110°[f], and probably, on some occasions, it rises still higher, at least locally. I have myself found it 107° under the tongue, in even acute rheumatism, and seen inflamed parts show this temperature, when the bulb of the thermometer was placed upon them and covered up. When a function is going on vigorously, the temperature of the individual part rises: as we observe in the genitals during sexual excitement. Certain parts of some animals are naturally of a lower temperature than the rest, v. c. the dog's nose. Disease will have the same effect. In affections of the stomach, its temperature will fall: so that the patient will not only complain of its coldness, but discharge fluid from it into the mouth that strikes cold immediately. In cancer of the bladder, I once saw a man complain greatly of the constant coldness of his glans penis. In old age it is not so high as in the age of full vigour; nor in remote parts as in those nearer the heart.[g] John Hunter made observations on the heat of cold-blooded animals.[h] The thermometer in the stomach and under the skin of the abdomen of the frog and toad stood at 40°, when the atmosphere was 36°; in the lungs of snails at 35°, 36°, 37°, 38°, when the atmosphere was 28°, 30°, 30°, and 34°; the heat of earth-worms was $58\frac{1}{2}$°, when the atmosphere was 56°. Fish are not above two degrees warmer than the water.[i] Cold-blooded animals placed in an elevated temperature are much more influenced by surrounding media than the warm-blooded. Yet frogs are but at 80° or 82° in a medium of 110° or 115°.[k] The heat of insects when congregated is considerable: J. Hunter found the thermometer rise to 93° or 98° in a hive of bees in

[d] *Exp. sur les effets qu'une forte chaleur produit sur l'économie.* Paris, 1805.
[e] Edwards, l. c. p. 489.
[f] Dr. Prevost. See Dr. Edwards, l. c. p. 490.
[g] Dr. Davy, *Phil. Transact.*, 1814.
[h] l. c. 298. sqq.
[i] *Edinburgh Journal of Science*, vol. iv.
[k] Dr. De la Roche, *Journal de la Physique*, t. lxiii.

spring; to 104° in summer; to be at 82° when the air was at 40°; and at 73° in winter.

The same tendency in vegetables is shown by the greater difficulty with which the juices in their stems and branches are frozen than lifeless fluids; by ice thawing when roots shoot into it[l]; and by snow upon the leaves or stems of plants thawing sooner than that which lies on surrounding inanimate bodies. J. Hunter observed a branch of growing fir and a bean leaf thaw the part of the surface of a freezing mixture on which it was placed, and the fir subsequently another to which it was removed.[m] When the sheath of the arum maculatum and cordifolium is bursting, and the cylindrical body just peeping forth, it is said, by Sennebier, to be so hot for some hours as to seem burning[n]; and twelve of them placed round the bulb of a thermometer to have raised the mercury from 79° to 143°.

Even eggs are cooled and frozen with more difficulty than equal masses of inanimate matter; although, when once frozen and their life destroyed, they freeze readily.[o]

"This natural temperature in man is so constant, equable[p], and perpetual, that, excepting slight differences from variety of constitution, it varies but a few degrees in the coldest climate and under the torrid zone. For the opinion of Boerhaave, — that man cannot live in a temperature exceeding his own, has been refuted, since the admirable observations[q] of H. Ellis, the celebrated traveller, and formerly the governor of Georgia, by the remarkable experiments[r] of many excellent physiologists."[s] Dr. Fordyce,

[l] *American Medical and Philosophical Register*, vol. iii. p. 19. 1814.

[m] *Phil. Trans.*, 1775.

[n] *An Introduction to Physiological and Systematic Botany.* By Sir J. E. Smith, M.D. p. 92.

[o] J. Hunter, l. c. p. 79.

[p] " J. B. Van Mons, *Journal de Physique*, t. lxviii. 1809, p. 121."

[q] " *Philos. Trans.* vol. i. p. ii. 1758.

Arn. Duntze had previously made the observation in regard to brutes. *Exper. calorem animalem spectantia.* Lugd. Bat. 1754, 4to.

Consult also Benj. Franklin, *Experiments and Observations on Electricity.* Lond. 1769, 4to. p. 365."

[r] " Duhamel and Tillet, *Mém. de l'Acad. des Scienc. de Paris*, 1704.

Blagden and Dobson, *Philos. Trans.* 1775."

[s] " The heat of the weather, even in Europe, occasionally exceeds our natural temperature. This was the case on the 3d of August, 1783, at noon, when I was on the Lucerne Alps, in company with the excellent Schnyder of Wartensee.

one of the most eminent of my predecessors at St. Thomas's Hospital, went successively into rooms heated to 90°, 110°, and 120°. In the first temperature he staid five minutes, and sweated gently. In the second, he sweated more profusely, and remained ten minutes. In the third, after remaining twenty minutes, the thermometer under the tongue and exposed to the urine was at 100°, the pulse was 145; the veins of the surface were enlarged, and the skin red. He afterwards entered a room heated to 130°, and staid 15 minutes: the thermometer under the tongue, in the hand, and exposed to the urine, was at 100°.

Sir Joseph Banks, Sir Charles Blagden, and Dr. Solander, went subsequently into rooms heated to between 196° and 211°,—about the temperature of boiling water,—and remained several minutes. If they breathed on the thermometer, it sunk several degrees, and every expiration felt cold to the scorched nostrils: the thermometer under the tongue was 98°, and the body felt cold to the touch, though at 98°. Sir C. Blagden remained eight minutes in an apartment heated to 260°. The air felt hot, and for seven minutes the breathing was natural, but anxiety and oppression then came on; the sensible heat of the body varied but little. Dr. Dobson went into a room heated to 224°, and felt no oppressive heat, though every metal about him speedily became hot. A bitch of moderate size was subjected to a heat of 220°. In ten minutes the only sign of distress was that of holding out the tongue, and when taken out at the end of half an hour, the temperature being at 236°, the bottom of the basket was found wetted with saliva. The thermometer applied to her flank was only 110°, *i. e.* 9° above the natural standard.

In these rooms, eggs on a tin plate were roasted hard in twenty minutes; beef-steaks cooked in thirty-three minutes; and, if the air was impelled upon them in a stream, they were cooked dry in about thirteen minutes.

Tillet and Duhamel relate that the young female servant of a baker at Rochefoucault went habitually into ovens heated to 276°, and remained without great inconvenience for twelve minutes, taking care not to touch the oven. These gentlemen themselves bore a heat of 290° for nearly five minutes. Dr. Delaroche and

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The thermometer in the shade stood above 100° Fahr., and, when applied to the body, invariably sunk to near 97°."

Dr. Berger found various warm and cold-blooded animals support from 108° to 113° for an hour and a half in heated dry air; but an elevation of about 30° beyond this killed them all, except a frog, in from half an hour to two hours. They themselves experienced a sense of scalding in a *vapour*-bath of 122°, and could not bear it more than about ten minutes; while M. Lemonnier could not bear a *water*-bath of 113° above eight minutes.[t] Hence, at the very same high temperature of the surrounding medium, there is more secretion by the skin in a vapour-bath than in dry air, and more in a water-bath than in a vapour-bath.

"The striking prerogative of man, in respect of bearing a variety of temperatures, is evinced by his being restricted to no climate, but inhabiting every part of the earth, from Hudson's Bay, where mercury freezes, and from Nova Zembla, to the scorching shores of Senegal."

At Sierra Leone, the mean temperature is 84°, and Watt and Winterbottom frequently saw it 100° and even 103° in the shade. At Senegal, it has been 108½°, and even 117½°. During the sirocco, it is 112° in Sicily; Humboldt saw it 110° and 115° near Oronoco, in South America. On the other hand, at Nova Zembla the cold is so intense that, when the sun sinks below the horizon, the polar bear is no longer seen, the white fox only enduring the cold. Yet the Dutch, who wintered there under Hemskerk (76° N. L.), withstood the cold, if moving about and previously in good health. When some of our countrymen were on Churchill River, in Hudson's Bay, lakes ten or twelve feet deep were frozen to the bottom, and brandy froze in their rooms, though provided with fires. They suspended in their rooms red-hot twenty-four pounders, and kept an immense fire: but, if these went down, the walls and beds were covered with ice three inches thick.[u] Yet in Hudson's Bay the Canadians and Esquimaux live and hunt in the coldest weather. Gmelin, sen. witnessed at Jeniseisk, in 1735, a cold of —20°, that froze mercury and killed all the sparrows and jays.[x] Captain Parry once observed a temperature of 52° below zero. When the air was at —49°, the party used to walk on the shore. It was usually at —32°. The temperature of eleven out of sixteen foxes was from 100° to 106¾°, of four about 100°, and of one only 98°, although the

[t] Dr. Edwards, l. c. p. 374., and indeed, see p. 4. ch. xiv.

[u] *Philosophical Transactions*, abridged, vol. iii. p. 470.

[x] *Flora Sibirica*. Preface.

air was from —3° to —32°. No relation was observable between the temperature of the body and of the atmosphere[y]; it thus appearing that the temperature is more steady under cold than heat. I may here remark that, if an animal is drowned in hot water, a puppy or kitten, for example, in water at 90° or 120°, the action of its heart irrecoverably ceases sooner than if it is drowned in cold water.[z] Under the want of respiration the heat is too exhausting for the powers of the system. When animals recover, they regain their warmth slowly, even more slowly, Mr. Nunnelly says, than after immersion in cold water. Oxygen also excites so much, that it exhausts and lowers the temperature.

Another wonderful circumstance is the impunity with which great *changes* of temperature are borne by persons in good health, and under neither mental nor corporeal accidental depression at the moment. The Russian, while in a vapour-bath of perhaps 167°, has several large vessels of cold water poured upon him: and the Finnish peasant passes reeking from it, and rolls in the snow, with exquisite delight. Sir Joseph Banks and the rest of the party passed from the high temperature mentioned into the cold air, and even staid some minutes before they dressed, without the least injury. During an unnaturally high temperature, the sudden application of cold is very agreeable.

No phenomenon in living bodies is more remarkable than their peculiar temperature, and no one was of more difficult explanation before the modern progress of chemistry. Dr. Mayow had indeed advanced, that it depended on respiration, and that this was a process similar to combustion, and, so far from cooling the blood, as others believed, supplied it with heat.

If two different bodies are placed in a temperature higher or lower than their own for a certain length of time, they will, at the end of the period, be found, not of the same, but of different temperatures. That which has the higher temperature is said to have a smaller capacity for caloric; that which has the lower, a greater capacity. To raise the former to a given temperature, therefore, requires less caloric than to raise the latter to the same degree.

[y] *Journal of a Second Voyage*, p. 157.

[z] Experiments by Sir Astley Cooper, in 1790, published from his MS.; by Dr. Hodgkin, in the translation of Dr. Edwards's work, p. 472. sqq. Similar results are there related by Mr. Nunnelly.

The temperature of solids is more easily affected by a given quantity of caloric, than that of fluids, and the temperature of fluids than that of aëriform bodies; or, in other words, solids have a smaller capacity for caloric than fluids; and fluids than aëriform bodies. If, therefore, a solid becomes fluid, or a fluid aëriform, it absorbs a great quantity of caloric, notwithstanding its temperature remain precisely the same. And the converse holds equally good:—if an aëriform substance becomes liquid, or a liquid solid, the caloric which it before contained is now, from its diminished capacity, much more than sufficient for the temperature which before existed, and the temperature of the body accordingly rises.

In respiration, the dark blood of the pulmonary artery parts with a portion of its carbon, and acquires a florid hue. Oxygen disappears, and carbonic acid is expired with the other constituent of the atmosphere — nitrogen or azote, which seems usually to have experienced little or no change from inspiration.

The celebrated Dr. Crawford of St. Thomas's Hospital appeared to prove, by his experiments, that the arterial blood has a larger capacity for caloric than the venous, and common air than carbonic acid gas. He therefore argued thus:—when the carbonic acid appears in the lungs, the smaller capacity of this than of common air for caloric, must cause an increase of temperature; but the blood, having changed from venous to arterial, has acquired a greater capacity than before, and absorbs the heat given out by the carbonic acid. The blood, of course, does not become warmer, because the caloric is not more than sufficient to render its temperature equal to what it was previously; and, indeed, according to some, it is not quite sufficient for this, since the temperature of the florid blood of the pulmonary veins has appeared two degrees lower than that of the pulmonary artery to some experimenters, although the greater number have found it a degree or two higher than the dark blood.

The body in this way acquires a fund of caloric, and yet the lungs, in which it is acquired, do not experience any elevation of temperature; or, if they do, this is very inconsiderable.

The arterial blood, charged with much caloric, which, as it circulates through the small vessels, is not sensible, becomes venous,—acquires a dark hue, and its capacity for caloric is diminished; consequently its temperature rises,—the caloric which was previously latent is, from the decrease of capacity, sufficient to raise its temperature, and is evolved. In this mode, the loss of caloric which occurs from the inferior temperature of the medium in which we live, is compensated. The fresh supply is taken in at the lungs, and brought into use in the minute vessels.

Dr. Crawford's theory afterwards fell into some discredit.

All experiments upon the capacities of bodies for heat are very delicate and liable to error; and the conclusions of Dr. Crawford on this point have been denied by Drs. Delaroche and Berard, with respect to gases, and by Dr. Davy, with respect to arterial and venous blood.[a]

The experiments of these chemists have led them to believe the difference of capacity less than Crawford supposed, and insufficient to account for animal temperature. With respect to the gases, Dr. Bostock[b] justly remarks, that the objection does not apply more to the doctrine of animal heat, than to the theory of combustion in general. Whenever carbon unites with oxygen, and carbonic acid is produced, caloric is liberated, whether in fermentation, or combustion, &c. With respect to the blood, he declares, and Dr. Bostock's reputation for accuracy and soundness in chemical matters is not little, that, "after attentively perusing the experiments of Crawford, and comparing them with those that have been performed with a contrary result, he confesses that the balance of evidence appears to him to be greatly in favour of the former, though he acknowledges that they are of so delicate a nature as not to be entitled to implicit confidence, and that it would be extremely desirable to have them carefully repeated."

If, however, it were true that Dr. Crawford's statement of the relative capacities is incorrect, still the fact of heat being necessarily evolved on the disappearance of oxygen in the lungs, and the appearance of carbonic acid, provided they unite there, would stand unaffected, and we should only be obliged to adopt the doctrine of Mayow, that the lungs are the focus of the heat of the body. This was relinquished, on the objection that the lungs should then be hotter than other parts. But, when we consider that the blood is incessantly streaming to the lungs from all parts and again leaving them, we may, I think, presume that the blood will always convey away their heat, and prevent their temperature from rising above that of other parts. The heat of all parts is, cæteris paribus, commensurate with the quantity of blood circulating through them, and this is equally explicable on the

[a] *Philos. Trans.* 1814. [b] l. c. vol. ii. p. 263.

supposition that the carbonic acid is formed in the lungs, or in the extreme vessels of all parts. If their heat is derived from the heat of the blood conveyed to them, the more blood streams through them, the hotter will they be; if from chemical changes in the blood while in them, the more blood streams through the extreme vessels the greater will be the amount of chemical change, and the greater the extrication of caloric. The quantity of blood, unless constantly renewed, is inefficient, on either supposition. On the first, fresh blood must come incessantly from the lungs with its high temperature; on the second, if not renewed, its chemical changes will cease, having already occurred.

As it is now generally believed that the oxygen which enters into the blood combines with the carbon, not in the lungs, but in all the extreme vessels, and in them forms carbonic acid, the evolution of heat throughout the body is thus at once explained, — it is a mere instance of combustion in the extreme vessels, the union of carbon and oxygen being always attended by an increase of temperature[c]; and we may equally abstain from troubling ourselves about relative capacities for caloric. The fact of local heats above the temperature of the general mass of blood, proves that heat is evolved by local processes. If arterial blood is made venous, or, more properly, blackened, by galvanism, heat is evolved, as I shall presently mention. Those who believe that venous blood has a larger capacity for caloric than the arterial, say that the heat evolved in the minute vessels, by the formation of carbonic acid, does not produce so high a temperature as it would, were the capacity of the blood for caloric not lessened by the changed character of the fluid: but, that, when rendered florid again in the lungs, its capacity is again reduced; and, not only is there sufficient caloric to raise the cold air to 98°, but the florid blood becomes one or two degrees higher than it was when venous in the right side of the heart. It is evident that, if the chemical changes which occur in the lungs are independent of life, and even take place out of the body, and the evolution of heat is a purely chemical phenomenon, it also will occur in

[c] If the combustion thus takes place in the universal extreme vessels, the opinion of Tiedemann and Gmelin, that the use of the liver is to liberate the blood of much carbon without its union with oxygen, will not be the less probable than if the union occurred ordinarily in the lungs. If carbon is copiously removed without uniting to oxygen and forming carbonic acid in the blood, we understand why the blood in high temperatures is less dark, is even florid.

the blood out of the body. Accordingly Sir C. Scudamore, exposing two portions of the same blood, under the same circumstances, the one to atmospheric air, the other to oxygen, found the temperature of the portion exposed to oxygen eight degrees higher at the end of eight minutes than that of the other.

It is possible that other chemical changes, which incessantly go on throughout the frame, also occasion heat to be evolved.

A host of circumstances show that our temperature depends upon respiration, and therefore upon chemical changes.

In high temperatures we have less necessity for the evolution of heat; in low temperatures, more. Accordingly, in the former, the arterial blood remains arterial,—is nearly as florid in the veins as in the arteries [d], and the inspired air is less vitiated; in low temperatures, the venous blood is extremely dark, and the inspired air more vitiated. [e] Some have imagined that the body remains at its standard high temperature by the refrigeration of the evaporating sweat. But, though this must contribute, it is not the sole cause [f]; for frogs lose as much proportionally to their size by evaporation as any other animal, yet they follow pretty closely the surrounding temperature. Whenever, on the other hand, the body itself heightens its temperature, as in fever, more oxygen is consumed by the lungs [g]; (in the cold stage of fevers we saw that less was consumed.) The temperature of the various classes of animals, and their vitiation of the air, are always proportional; and inverse to the length of time they can live without air.

[d] Dr. Crawford, l. c. p. 387. sq. Dr. De la Roche, l. c.

[e] Dr. Crawford, ib. " C. Ferd. Becker, *De Effectibus caloris et frigoris externi in c. h.* Gott. 1802. 4to.; and Wm. Fr. Bauer, *On the same subject.* IB EOD. (BOTH HONOURED WITH THE ROYAL PRIZE.)

Mich. Skjelderup, *Dissert. sistens vim frigoris incitantem.* Hafn. 1803. 8vo."

Yet, in the account of Sir Astley Cooper's experiments, quoted at p. 235., it is mentioned that a puppy and a kitten, some weeks old, were placed nearly to the mouth in iced water, till they died; and that the blood of the lips, nose, toes, mesentery, and left side of the heart, was of a fine vermilion hue. The colour of the venous blood is not mentioned. I should presume it was very dark, but that the oxygen, from the great coldness of the air inspired, was so effective in withdrawing the carbonic acid, that the arterial blood was, on this account, unusually florid.

[f] Dr. Edwards, l. c. p. 488.

[g] See supra, p. 222.

The temperature of young animals is lower than of adults, or rather they maintain a peculiar temperature much less, are more easily cooled and heated, and they vitiate the air less, and require respiration less, proportionally, than adults.[h] As they proceed to vitiate it more, and require respiration more, their calorific power increases. While their calorific powers are weak, they breathe, if they are exposed to cold, more quickly, so as to keep up their temperature as much as possible.[i] The same we shall find is true of adult warm-blooded animals, not of the hybernating family, when exposed to cold.

Dr. Edwards found that habit has great influence on the calorific powers of animals; — that a given low artificial temperature in winter will reduce the animal heat much less than in summer[k]: and that, with the habit of evolving more heat in winter, is acquired the habit of consuming and requiring more oxygen, so that animals supplied with a given quantity of air, and placed in a given warm temperature in winter, die much sooner than in summer.[l] Yet the *momentary* application of heat or cold has a different effect: the former heating less if the body has been subjected to a low, and the latter cooling less if the body has been subjected to a high, temperature. We all feel the cold less quickly on leaving the house in winter if well warmed first, than if we leave it already chilly.

When animals hybernate, their temperature falls, and respiration is nearly or entirely suspended.[m] Their consumption of air lessens as the temperature falls, whence they consume less in November than in August.[n] If hybernating animals, while torpid and still placed in the same temperature, are stimulated mechanically to breathe, their temperature rises with the progress of respiration.[o]

If the cold to which they are exposed is so intense that it threatens death, it actually no longer depresses respiration, but, for a time, excites it, and their temperature rises proportion-

[h] Dr. Edwards, l. c. p. 165. sqq.
[i] l. c. pp. 299. 310.
[k] l. c. p. 162. sqq. 252. sqq.
[l] l. c. p. 200. sqq.
[m] Spallanzani, *Mémoires sur la Respiration*, p. 77. De Saissy could not by cold produce torpor in a marmot, till he had deprived it of fresh air. Edwards, l. c. p. 154.
[n] M. de Saissy. See Edwards, l. c. p. 286.
[o] M. de Saissy. See Edwards, l. c. p. 305.

ally.[p] Man and other non-hybernating animals breathe more quickly when exposed to cold (no doubt for the purpose of supplying heat) till the powers become exhausted.[q]

The higher the temperature of the animal, the more extensive is the aggregate surface of the air-cells, the more blood passes through its lungs, and the more necessary to its existence is respiration.— The lungs of cold-blooded animals are not subdivided into minute cells, but formed into vesicles; and birds, which have the highest temperature among animals, are drowned the soonest.[r] Respiration is much slower in the cold-blooded. Dr. Stevens found an alligator breathe but three or four times in a minute, though young, and agitated at being held.[s]

The changes of the air by the blood are seen to be effected entirely by the red particles. Prevost and Dumas found that the number of red particles is proportionate to the temperature.

If the blood circulates without being first properly changed in the lungs, the temperature is below the natural standard. Those who have the blue disease (cœruleans[t]), some of whose blood reaches the left side of the heart without passing through the lungs, are cold: and coldness is a symptom of hydrothorax, and of the repletion of the air-cells with mucus in chronic bronchitis; in the former of which affections the lungs cannot fully expand; and in the latter the air is prevented from coming fully in contact with the air-cells, and mucus Priestley found to be a barrier to the influence of oxygen on the blood. (p. 149.)

In cold climates, and in temperate ones in cold weather, animal food is desired and taken in abundance; in hot climates, and during the summer in temperate regions, light vegetable food is preferred, and the appetite is less. We may conceive the former diet more calculated to support a process similar to combustion, and under the former circumstances we have seen that the changes of the air in the lungs are actually more considerable.

[p] Dr. Edwards, l. c. p. 306. sq. [q] l. c. p. 301.

[r] Boyle's *Works*, vol. iii. p. 368. [s] l. c. p. 35.

[t] "Sometimes the septa of the heart are imperfect, sometimes the aorta arises with the pulmonary artery from the right ventricle, as in the tortoise. In such instances, the chemical changes can take place in the lungs but imperfectly.

Consult a host of cases in J. C. Hein's *Diss. de istis Cordis deformationibus quæ sanguinem venosum cum arterioso miscere permittunt*. Gotting. 1816. 4to."

Mr. Allan Burns, *Essay on Diseases of the Heart*, and Dr. Farre, *Treatise on Malformation of the Heart*, give accounts of these cases. See also Andral.

Warm-blooded animals are continually eating; birds, whose temperature is the highest, incessantly, if they can obtain food; whereas the cold-blooded eat little and seldom. Some make a meal only once in three or more months; Dr. Stevens saw a large rattle-snake, plump, active, and venomous, which was said not to have tasted food for nine months.[u]

The temperature of parts falls if not maintained by a constant stream of blood from the lungs through the aorta and its ramifications, and is, cæteris paribus, in exact proportion to this supply. When parts shrink, and are pale, they are cold from want of blood: when they do not shrink, or they are even full, turgid, and purple, they are cold from the want of *changed* blood. Still for a time respiration may not be quick and yet the temperature high, as in the yellow fever of the West Indies[v]: combustion may go on rapidly in the extreme vessels of a part or the whole of the body, for a limited period, disproportionately to the removal of the product,—the carbonic acid,—in the lungs, and the supply of oxygen for the combustion. On the other hand, general or local temperature may be low though respiration be rapid, for it may carry off carbonic acid and supply oxygen to little purpose, if the circulation in the extreme vessels languishes.

Whether the theory be correct or not, the production of animal heat must be as evidently a chemical process, as changes of temperature among inanimate bodies; yet some ascribe it to nervous energy. I cannot imagine nervous energy to cause heat any more than to cause chemical affinity. As it may bring substances into proximity which have an affinity for each other, and thus produce their union, so it may effect those changes which are, according to physical laws, accompanied by changes of temperature; but caloric in the body must, I apprehend, like affinity, follow the same laws, and no others, as out of the body. This, however, does not prevent animal temperature from deserving the epithet vital, because it is regulated by the vital powers of the system, although through the instrumentality of chemical changes. If the high temperature of an inflamed part is owing to the increased momentum,—the increased sum of the quantity and velocity of its blood,—yet this increased momentum is produced by the vital powers.

Sir B. Brodie removed the brain of animals, and continued

[u] l. c. p. 35.

[v] Dr. Stevens, l. c. p. 33.

respiration artificially. The usual chemical changes of the blood continued in the lungs; yet the temperature of the animals diminished, and even more rapidly than if the respiration had not been continued, owing, it is said, to the succession of cool air sent into the lungs. He therefore concludes that animal heat depends much more upon the nervous energy than upon the chemical changes of the blood.[x] But this experiment proves nothing; because Dr. Le Gallois asserts that, under artificial respiration the temperature may fall, and the animal actually be killed by cold, even though every part remain uninjured.[y] In artificial respiration the air does not rush into the pulmonary cells, because these are in a vacuum; but is propelled into, and forcibly, and therefore injuriously, dilates them: the consequence is, the formation of a large quantity of frothy mucus. Whether the fall of temperature be owing to the evaporation of this copious secretion and its prevention of contact between the air and air-cells, or to the injurious nature of artificial respiration, still the fact ascertained by Le Gallois destroys the conclusion which appeared deducible from Sir B. Brodie's experiment. Indeed, Le Gallois found that less oxygen was consumed than in natural breathing, and that the temperature fell exactly in proportion to the smallness of the quantity of oxygen consumed. Dr. Crawford himself stated that the chemical process of respiration may, in certain cases, be the means of cooling the body. If the pulmonary exhalation, he said, is in very great abundance, it will carry off so much of the heat, given out during the change of the oxygen into carbonic acid, that there may not be sufficient to saturate the increased capacity of the arterial blood: this, therefore, will absorb caloric from the system, as it passes along, till its temperature equals that of all parts.[z] I may here remark, that the

[x] *Phil. Trans.* 1812. [y] *Expériences sur le Principe de la Vie.*

[z] *On Animal Heat*, p. 388. Instances are recorded by Morgagni (iv. xlix. 26.), and De Haen (*Ratio Medendi*, vol. iii. p. 36.), in the German *Ephemerides* (Dec. ii. Ann. iv.), and by Mr. Thackrah, of the blood which streamed down the extremity in venesection feeling cold to the patient and the practitioner. One woman compared it to ice; and the sensation given to Mr. Thackrah was the same as that of water at 68°. (Thackrah, *On the Blood*, p. 87.) In the *Ephemerides* the same is recorded of blood from the nose. The stomach of a cod was found by Dr. Mosely to be not only colder than the water from which it was taken, and the rest of the fish, but painfully to benumb the hand. (*Diseases of Tropical Climates.*) Similar observations were made at Newfoundland, and are quoted by Professor Rudolphi. (*Grundriss der Physiologie*, 182.)

temperature is kept down in a heated atmosphere by the diminution of chemical changes in the lungs, and by free secretion and evaporation from the bronchiæ and skin. How much each contributes is not ascertained; but the importance of evaporation was shown in some experiments of Dr. De la Roche, who raised the temperature of animals considerably by placing them in a heated atmosphere loaded with moisture; thus preventing evaporation. In a cold atmosphere, the chemical changes in the lungs are great, and the skin is dry: the aqueous matter which leaves the body then, does so chiefly by the kidneys, in a fluid form; and its amount is much less; because our thirst, and the amount of our drink, are much less.

Dr. Philip has made experiments equally conclusive with those of Dr. Le Gallois against the inferences drawn by Sir B. Brodie. As very little air is taken into the lungs in natural inspiration, and a regard to the bulk and frequency of each inspiration not always attended to in experiments, it is very probable that this gentleman had thrown too much air into the lungs; so that the unnatural quantity of cold air, and the augmented secretion of bronchial fluid, made the temperature fall. By impelling little, and that not frequently, Dr. Philip found that artificial respiration, after the destruction of the brain, actually retarded the cooling of the animal, while stronger respiration did actually cool the body.

Of two rabbits killed in this way, their temperature being 104°, one was subjected to 6 artificial inspirations, and the other to from 26 to 30, in a minute; the temperature of the former was 100° at the end of an hour, and the latter 98°. Of two, with the temperature of 102°·5, one was undisturbed, and one subjected to about 30 inspirations in a minute: the temperature of the former at the end of half an hour was 98°·75; of the latter, only 98°·5. But, the lungs of the latter being now inflated only about twelve times in a minute, the temperature of the former at the end of another half hour was 95°·25, and of the latter, 96°. In one experiment in which the lungs were inflated but a few times in a minute, the temperature actually rose nearly a degree by artificial respiration.[a] Dr. Hastings, at the same time, made similar comparative experiments, and with similar results. In one, the

[a] *An Experimental Inquiry into the Laws of the Vital Functions*, 3d edit. p. 180. sqq.

rabbit in which artificial breathing was performed cooled only 4°; while that which was left undisturbed cooled 7°·5.

Dr. Philip afterwards took pairs of rabbits, killed them in the same way, and then in one experiment destroyed the brain and spinal marrow of one with a wire, while he left the other untouched: in another experiment, precisely similar, he inflated the lungs of both. Yet, in each experiment, they both cooled equally. In a third, the brain and spinal marrow of one only was destroyed, and the lungs of both inflated. These, too, cooled equally.

The temperature of fœtuses born without brain is maintained during the few days they may live.

Professor Rudolphi remarks that the temperature of animals bears no proportion to their nervous system: that, if it did, man should be warmer than any brute; the mammalia much more so than birds; fish much more so than insects; and birds and amphibia nearly upon a par; — all which would be the reverse of fact.[b]

Vegetables have a tendency to preserve a peculiar temperature, yet they have no nervous system.

But that the nervous system affects the temperature is certain.[c] A passion of the mind will make the stomach or the feet cold, or the whole body hot. Paralysed parts are often colder than others, or, more properly, are more influenced than others by all external changes of temperature.[d] But every function is affected by the mind, though not dependent upon the brain for its regular performance: and in varieties of temperature, both by the state of the mind and by paralysis, there is, as far as we can judge, a commensurate affection of the local circulation. Parts heated by any passion are also red, and *vice versâ;* and paralytic parts must have imperfect vascular functions, in some measure, at least, from the want of the compression of the vessels by muscular action, and of the general excitement by volition; they waste, and sometimes inflame and ulcerate, or slough, on the slightest

[b] *Grundriss der Physiologie,* 150.

[c] "I have formerly treated at some length of the influence of the nervous system upon animal heat, in my *Specimen Physiologiæ Comparatæ inter animantia calidi et frigidi sanguinis.* 1786. p. 23.

See the same confirmed by many arguments in Magn. Ström, *Theoria inflammationis doctrinæ de calore animali superstructa.* Havn. 1795. 8vo. p. 30. sq. and by the much-lamented Roose, *Journal der Erfindungen, &c.* t. v. p. 17.

Consult also Dupuytren, *Analyse des Travaux de l'Institut,* 1807, p. 16."

[d] Dr. Abercrombie, *Edin. Med. and Surg. Journal.*

injury. Again, parts perfectly paralysed still maintain a temperature above that of the surrounding medium, as well as circulation, secretion, &c.[e], and sometimes the same as in health.

Dr. Philip considers galvanism an important agent in the nervous system, and found that it raised the heat of *fresh arterial* blood 3° or 4°, and, at the same time, made the blood dark; a circumstance proving that the action is purely chemical, — an alteration of some constituents of the blood to that state in which their capacity for caloric is less.[f]

There is certainly no more reason to believe animal heat dependent on the nervous system, than secretion and every organic function. That, like these, it is influenced by the state of the nervous system, is certain; but never, I imagine, except through the instrumentality of chemical changes.

The purpose of animal heat is no doubt the performance of the processes of the animated system, chemical, electrical, and vital, which cannot continue unless at a certain temperature, nor unless a certain degree of fluidity is preserved in some constituents of the system, and of solidity in others.

[e] Dr. Philip, we have seen, found rabbits just killed cool in exactly the same time, whether the brain and spinal marrow were destroyed or not, although when these were destroyed a stop was put to the secretion of gastric juice. Yet when the same was done to a living rabbit, with the same effect on the stomach, the animal's temperature fell. This, however, would result from the shock given to the nervous system as merely a part of the body, for the same happens every day in cases of severe injuries even of the extremities.

[f] *Experimental Inquiry*, p. 230. sqq.

Vegetables and animals are prepared for almost all climates, and for temperatures higher than the heat of any country. Dr. Reeve found larvæ in a spring at 208°; Lord Bute, confervæ and beetles in the boiling springs of Albano, that died when plunged into cold water. A species of chara will flower and produce seed in the hot springs of Iceland, which boil an egg in four minutes. (Drs. Hodgkin and Fisher's translation of Dr. Edwards's work, p. 467., where will be found many curious facts of this nature, though less striking.) One plant, *uredo nivalis*, which is a mere microscopic globule, is said to grow and flower under the snow.

Some cold-blooded animals bear heat very badly. Dr. Edwards says that frogs die in a few seconds in water at 107°. (l. c. p. 40.) Yet a species of tænia has been found alive in a boiled carp; but then the carp which it inhabits will live in water as hot as human blood. (Sennebier, Notes to his *Translation* of Spallanzani.)

The germs of many insects, &c. are unaffected by a great range of temperature. I know a gentleman who boiled some honey-comb two years old, and, after extracting all the sweet matter, threw the remains into a stable, which was soon filled with bees. Body lice have appeared on clothes which had been immersed in boiling water. Spallanzani found long ebullition in the open air favourable to the appearance of the animalcules of vegetable infusions; and the application of great heat in close vessels, although it prevented the appearance of a larger kind of animalcule, did not that of a smaller. The eggs of silk-worms and butterflies hatch after exposure to a cold of 24° below zero. On the other hand, insects may be frozen repeatedly, and recover as soon as thawed, as we shall see when speaking of torpidity.

Besides the power of generating heat, some animals are luminous, and some display great electric phenomena.

The glow-worm is known to all; and many insects of the beetle tribe, as well as others, emit light. Many can extinguish or conceal their light, or render it more vivid, at pleasure. In some it has been found to proceed from masses not dissimilar, except in their yellow colour, from the interstitial substance of the rest of the body, lying under the transparent integuments, and absorbed when the season of luminousness is passed. (Consult Kirby and Spence, *An Introduction to Entomology*, vol. ii. p. 409. sqq.) The ocean is frequently luminous at night from the presence of certain animalcules, to some sort of which, perhaps, is owing the phosphorescence of dead herrings. Some fish, as the gymnotus electricus and torpedo, give electric shocks, and possess a regular galvanic battery.

I have adopted the common language in speaking of animal heat, as though the phenomena depended upon a specific substance. However, there may be every reason to believe that neither caloric nor light are fluids, but peculiar states only; and electricity may prove to be so likewise; and, perhaps, all these to be modifications of the same state.

CHAP. XIV.

NUTRITION.

" Besides the function of distributing oxygen through the system, and removing carbon, the principal use of the blood is to afford nourishment to the body in general, and to the secreting organs the peculiar fluids which they possess the power of deriving from it. Nutrition shall be first examined.

" *Nutrition* is the grandest gift of nature, and the common and highest prerogative of the animal and vegetable kingdoms, by which they, beyond measure, surpass, even at first sight, all human machines and automatons. Upon these no artist can bestow the faculty, not to say of increasing and coming to perfection, but even of existing independently, and repairing the incessant losses incurred from friction.[a]

" By the nutritive faculty of the body, its greatest and most admirable functions are performed; by it we grow from our first formation and arrive at manhood; and by it are remedied the destruction and consumption which incessantly occur in our system during life.[b]

" Respecting the nature of this consumption, there has been much dispute whether it affects the solids [c], or whether, accord-

[a] " ' Nutrition, in fact, appears to be a continued generation,' according to the old observation of the very ingenious Ent. See his work, already recommended."

[b] " Th. Young, *De corporis humani viribus conservatricibus.* Gotting. 1796. 8vo. Fl. J. Van Maanen, *De natura humana sui ipsius conservatrice ac medicatrice.* Harderv. 1801. 8vo."

[c] " See the great J. Bernouilli's *Diss. de nutrit.* Groning. 1669. 4to. He estimates the continual, though insensible, loss and reparation of the solids so high, that the whole body may be said to be destroyed and renewed every three years."

ing to some very acute writers[d], these, when once formed and perfected, remain invariably entire.

"There can be no doubt that some of the similar solids, *v. c.* the epidermis and nails, are gradually destroyed and renewed; the same is proved by the frequently surprising attenuation of the flat bones, especially of the skull, from defective nutrition, in old age[e]; and" some imagine "it is proved also by the well-known experiment of dyeing them, in warm-blooded animals, with madder root."

But the redness imparted to the bones by feeding animals with madder, does not prove that the matter of the bones is constantly changing; because the opinion that the madder unites with the phosphate of lime in the blood, and thus reddens all the bony matter subsequently deposited, is erroneous. Mr. Gibson proved, by numerous experiments, that the serum has a stronger affinity than the phosphate of lime, for madder. The serum being charged with madder, the phosphate of lime of the bones, already formed, seizes the superabundant madder, and becomes red. If the madder is no longer given to the animal, as it is continually passing off with the excretions, the stronger attraction of the serum draws it from the bones, and they re-acquire their whiteness.[f] The attenuation of the flat bones shows, I imagine, wasting only.

The constant renewal of the epidermis is demonstrated by wearing black silk stockings next the skin. The microscope exhibits that very minute fragments are incessantly thrown off from the mucous membranes no less than from the skin.[g] That the hair and nails not only grow perpetually, but are even reproduced, is certain from the great quantity of the former which falls off the head *whole* if worn long, while a good head of hair still continues; and from the renewal of the latter, after the loss of a great part of a finger. I once attended a middle-aged woman in St. Thomas's Hospital, who had lost nearly the whole of the first phalanx of a finger, and yet the stump was tipped by

d "See J. Chr. Kemme, *Beurtheilung eines Beweises vor die Immaterialität der Seele aus der Medecin.* Halle. 1776. 8vo.

And his *Zweifel und Erinnerungen wider die Lehre der Aerzte von der Ernährung der festen Theile.* Ibid. 1778. 8vo."

e "Respecting this mutability of the bones, I have spoken at some length in my osteological work, ed. 2. p. 26. and elsewhere."

f *Manchester Memoirs*, vol. i.

g Raspail, l. c. pp. 245. 505.

a nail, though certainly a clumsy one. An instance of a nail at the end of the stump, after the complete removal of the first phalanx, may be seen in one of our London Journals.[h] Tulpius declares he has seen examples after the loss of both the first and second phalanges — in secundo et tertio articulo.[i] The glans penis (in truth a mere continuation of the corpus spongiosum urethræ) was entirely renewed in one case.[k] Nothing more can, I apprehend, be said respecting the entire restoration of organs in the human body. Portions of cutis, bone, membrane, blood-vessels, absorbents, and nerves, are replaced. That portions of large nerves, fully capable of all the functions of the destroyed pieces, are reproduced, is now a matter of certainty.[l] Minute blood-vessels and absorbents are of course allowed on all hands to be produced in the cure of most solutions of continuity, whether by wounds, ulceration, or whatever else[m]; but Dr. Parry, senior, has shown, that, in the ram, at least, when a blood-vessel which proceeds some way without giving off a branch is obstructed, new branches sprout forth and establish a communication on each side

[h] *London Medical and Physical Journal*, 1817.

[i] *Observationes Medicæ*, iv. 56.

[k] *Edinburgh Med. and Physical Essays*, vol. v.

[l] The proofs of this are numerous; the latest are by Tiedemann. *Zeitschrift für Physiologie*, 4ter band, 1ter heft, S. 68.

[m] Mr. Bauer thinks he has observed vegetable tubes to be constructed by the extrication of carbonic acid gas into a slimy matter prepared for nutrition. Some such opinion was held by Borelli, Tabor, and Hales. He explains the formation of blood-vessels in coagulated fibrin and pus in an analogous manner, but his experiments did not proceed far enough for me to dwell upon them. *Phil. Trans.* 1818 and 1819. Dr. Stevens has recently made observations upon this subject. (l. c. p. 66.)

Not only divided parts re-unite, but even portions completely separated and cold, and parts of different bodies. A soldier's arm was struck off at the battle of Arlon, with the exception of a piece of skin and the subjacent vessels and nerves, and yet the muscles, bones, &c. completely re-united in about eight months. (*Dictionnaire des Sciences Médicales*, t. xii.) Garengeot saw a nose unite after being bitten off, trampled upon, and allowed to lie in the dirt till it was cold. (*Traité des Opérations de Chirurgerie*, t. iii.) Dr. Balfour saw a similar occurrence in the instance of a finger. (*Edinburgh Med. and Surgical Journal.* 1815.) One will be found (Rust's *Magazin*, 14 b. 1 h. p. 112. Berlin, 1823.) by Dr. John, *Wiederanheilung eines gänzlich absgeschittenen fingers.* Others might be quoted. See Dr. Thomson's *Lectures on Inflammation*, p. 243.

Transplantation, for instance, of the cock's testes to the hen's abdomen, as well as of the spur to the head, is very common, and the latter was mentioned nearly two centuries ago in Bartholin, *Epist.* Cent. i. p. 174.; and by Duhamel, in the *Mém. de l'Acad. Royale des Sciences*, 1746, as very common in poultry-yards.

of the obstruction.[n] The continuance of circulation was previously attributed solely to the enlargement of the small anastomosing vessels; and we know that whenever the aorta itself is obstructed, branches will so enlarge as to carry on the circulation very well.[o] Muscle is supplied by tendinous matter. The substance formed in the situation of destroyed cellular membrane is so little cellular, that it does not become distended in emphysema or anasarca.[p]

" If I am not mistaken, those solid parts undergo successive change, which possess the *reproductive power*, — an extraordinary faculty, by which not only the natural loss of particles, but even the accidental removal of considerable parts through external injuries, is repaired and perfectly supplied, as the bones[q] and a few other parts sufficiently demonstrate.

" In those parts whose vital powers are, as it were, of a higher order, the parenchyma, constituting their base, appears permanent, and is liable to this change only, — that the interstices of the fibres and parenchyma, while nutrition is vigorous, are constantly full of nutrient animal" soft substance; " but, when nutrition languishes, are deprived of this, collapse, and consequently become thin." The very convolutions of the brain will shrink in extreme emaciation.

" During the growth of the body, peculiar powers are exerted, by which the fibrin deposited in the cellular membrane from the blood-vessels is properly distributed and intimately assimilated to the substance of each organ, &c.

[n] *An Experimental Inquiry, &c.* See also Dr. Charles Parry's work, in which similar experiments are related.

[o] See a case in the *Dublin Hospital Reports*, vol. ii. *Med. Chir. Trans.* vol. v.

[p] Dr. Thomson, *Lectures on Inflammation*, p. 417.

[q] " Consult, among others, G. L. Koeler, *Experimenta circa regenerationem ossium.* Gotting. 1786. 8vo.

Alex. Herm. Macdonald, *De necrosi ac callo.* Edinb. 1799. 8vo "

" That the corium is not really reproduced, is probable, not only from its perpetual *cicatrices* (for some contend that the *matter* of these does not continue, but their *form* only, which is preserved by a perpetual apposition of fresh particles in the room of the decayed and absorbed), but much more by the lines and figures which are made upon the skin by the singular art of pricking it with a needle (a process denominated in the barbarous language of the Otaheiteans *tatooing*), and imparting to the corium a blue or red colour, as permanent as the cicatriculæ, by means of charcoal powder, ashes, soot, the juices of plants, or ox-gall; while, on the other hand, the red hue imparted to the bones, by means of madder, quickly disappears, as these parts undergo a continual renovation."

"This is referable both to the laws of affinity" and repulsion, "by the former of which we imagine particles attract and, as it were, appropriate others which are similar and related to themselves," while by the latter others are cast off; and to the peculiar powers of life which only can effect "the proper application of shapeless elementary matter, and its modification to particular forms." The blood contains either the principles themselves of various solids, or principles readily converted into them by chemical change. For instance, we know how readily a portion of it grows solid out of the body; and the albumen of the egg is at first almost entirely fluid, but gradually a portion of it becomes insoluble[r]; we see mucus expectorated sometimes of great consistence, though it must have been poured forth fluid. Farther, the fluids of the egg, after the influence of the fluid of the male, solidify by themselves, and at length form an animal. A coagulum of blood will of itself become vascular, and be converted into an organized solid. Such are facts of formation, and we can have less difficulty in conceiving that the fluids brought into proximity with solids unite with them in the case of nutrition. We know also that gelatine enters into the composition of every part, and that the skin is little else, whereas the blood contains none: but then gelatine differs from albumen, in only containing three or four per cent. less carbon, and carbon is thrown off from the body incessantly.

"The union of both these powers, we conceive, must be the source of the nutrition of such similar parts as are not supplied with blood itself, but are, nevertheless, at first generated by a most powerful and infallible nisus, grow, are nourished throughout life, and, if destroyed by accident, are very easily reproduced.[s]

"As this appears to be the true account of nutrition in general, so, on the other hand, this function evidently has great varieties of degree and kind," generally and locally, "especially where, from the more or less lax apposition of the nutritious matter, the structure of the similar parts is more or less dense, and the specific weight of the whole body more or less considerable.[t] In this

[r] M. Raspail, l. c. p. 194.

[s] "*Zwo Abhandlungen über die Nutritionskraft welche von der Acad. der Wiss. in St. Petersburg den Preiss getheilt erhalten haben.* Petersburg. 1789. 4to.

De Grimaud, *Mémoire sur la nutrition qui a obtenu l'accessit.* Ib. same year. 4to.

Steph. J. P. Housset, on the same subject (in the same school) in his *Mémoires physiologiques et d'hist. naturelle.* Auxerre. 1787. 8vo. t. i. p. 98."

[t] J. Robertson, On the specific Gravity of living Men. *Phil. Trans.* vol. l. P. i. p. 30. sq.

respect, not only individuals, but whole nations, differ from each other. The Yakuts and Burats, who are remarkable for the lightness of their bodies, are a sufficient example of this."

A certain degree of excitement and use causes parts to be better nourished, so that the exercise, for instance, of muscles, is seen to render them larger, and disuse to cause them to waste. Great excitement and excessive use exhaust and also occasion a part to waste. Organs, or some one or more of their component tissues, will, without very clear reasons, sometimes be over-nourished, hypertrophied; or under-nourished, atrophied; and different tissues of the same organ are sometimes oppositely affected. Nutrition is sometimes perverted, so that consistence, or even texture, is changed. Occasionally the structure of a part is changed to that of some other part—is transformed: and occasionally structures are produced altogether foreign to the body.

Brutes far surpass man in both the ordinary renewal of the integuments and appendages, and in the extraordinary restoration of destroyed organs. The horse periodically sheds its hair, the bird its feathers [u], the stag its horns, the serpent its cuticle, the lobster its shell and the teeth which are in its stomach. [x] The fall of the leaves of trees is an analogous circumstance. Insects not only change their coats frequently, but undergo complete metamorphoses; are first worms, then grubs, and finally winged beings. The crystalline lens extracted from a healthy eye is speedily reproduced in cats, dogs, and rabbits [y], and probably in other brutes. The extraordinary reproductive power of some brutes is almost incredible. A lobster can reproduce a claw; a water-newt an extremity: Blumenbach actually observed the reproduction of the whole head with its four horns in a snail, and the complete eye — cornea, iris, crystalline lens, &c. — in a water-newt. [z] Besides greater powers of reproduction than man, brutes generally possess greater also of reparation — will survive injuries which would prove fatal to us, perhaps under any circumstances, or at least without great care. I related Brunner's numerous attempts upon the life of a dog, of which, violent

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[u] Feathers which are not cast off, have been discovered to receive an increase of colour at the moulting season. *Linnæan Transactions.* 1818.

[x] This corroborates the propriety of the view taken by Dr. Prout in an unpublished paper written many years ago, in which he contends that the teeth are to be arranged with the integuments. A similar opinion has been lately published in France.

[y] MM. Cocteau and Le Roy d'Etiolle. Magendie's *Journal de Physiologie.* Janvier, 1827.

[z] *Göttingen Literary Notices.* 1787. pp. 28. 30.

as they were, " vim elusit, vegetusque evasit," as an illustration of this. Less violent injuries are recovered from with far less danger and inconvenience than we experience. The lower we descend into the scale, the greater tolerance of violence and the greater powers of reparation and renewal do we observe. When a salamander's head has been cut off, the wound has healed. (Dr. Edwards l. c. p. 11.) If the head of a planaria from our ponds is divided longitudinally a certain way, the wound heals: if completely, other new matter will be deposited and join the two heads into one of great size, with one or two additional eyes; or each half will become a new head. If the whole body is divided, except at the tail, Siamese twins are made, which pull discordantly and tear asunder their bond of union, and become independent. Not only does a planaria acquire a new head after decapitation, but, if the two heads which have been produced by division are removed, others have sprung up three times in succession, and, the animal being then divided throughout and its head cut off, one head only was now produced. If the animal is divided across, the anterior half swims off, and even sends forth a tail: the tail sinks, but after a few days sends forth a head. If cut across into three, the anterior and posterior proceed thus, and the middle part shoots forth both a head and tail. Nay a planaria has been cut into ten pieces, and each has become a perfect animal. (Dr. Johnson, *London Medical Gazette*, Feb. 10. 1832.) Some mites live in alcohol, and flies have come to London in a pipe of Madeira and revived. I have soaked a caterpillar in Scheele's prussic acid, and seen it recover in half an hour. If the polype, which is a gelatinous tube, with one end closed and the other fringed for the purpose of receiving food and conveying it, is divided, the two halves change at one end, the one closing, the other acquiring fringes, so that both halves become perfect animals; or, if a polype is inverted, the outer surface forms a digesting cavity.

Vegetables endure extreme violence. A log of mulberry-tree has sent forth shoots on being placed in the ground as a post, after many years of neglect; a gooseberry-bush will grow if planted with its branches in the earth and its roots in the air.

CHAP. XV.

SECRETION.

"Besides the products of nutrition, *fluids* of extremely various descriptions are produced from the blood by means of *secretion*, which Haller, no less than his predecessors, with truth and regret declared to be among the most obscure parts of physiology." [a] While nutrition is the production of the component solids from the blood, secretion is thus the production of fluids from it, by vital processes. The nature of the process in both must be the same. The solid products of nutrition are also said by many to be first deposited in a fluid state.

"The secreted fluids differ, on the one hand, so considerably among themselves, and, on the other, have so many points of resemblance, that their classification cannot but be extremely arbitrary. If we arrange them according to the degree of difference between them and the blood from which they are formed, they will stand in the following order:—

"First, the *milk*, which may be in some degree considered as chyle reproduced, and appears formed by the most simple process from the blood newly supplied with chyle.

"Next, the *aqueous* fluids, as they are commonly denominated from their limpid tenuity, although the greater part differ importantly from water in the nature of their constituents, and especially in the proportion of albumen: such are the humours of the eye, the tears, in all probability the vapour contained in the cellular interstices and the cavities of the abdomen and thorax; nearly similar, also, is the fluid of the pericardium and of the ventricles of the brain." They contain mucus, soda, hydrochlorates, and phosphates.

[a] "Fouquet on Secretion, in the Encyclopedical Dictionary of Paris, t. xiv.
Fr. L. Kreysig, *De secretionibus*. Sp. i. ii. Lips. 1794. sq. 4to.
Ignat. Döllinger, *Was ist Absonderung, und wie Geschicht sie?* Herbipol. 1819. 8vo."

"The liquor amnii of pregnancy, and the *urine*, remarkable for the peculiar nature and mixture of its proper constituents, are generally enumerated among these.

"The *salivary fluids*, concerned in mastication, digestion, and chylification, appear more elaborated.

"Next the *mucous*, which line the cavities of most of the organs performing the natural and genital functions, and likewise the tract of the nostrils, larynx, and trachea.

"The mucus within the eye, and under the epidermis, is nearly similar.

"In the same class may be included the cerumen of the ears, the unguent of the Meibomian glands and of the joints, and, perhaps, the ambiguous and nameless fluid commonly poured forth by the vagina during the venereal œstrum." Mucus contains an abundance of hydrochlorate of soda, and differs in different parts. That of the nostrils and bronchiæ at first coagulates in nitric acid, and at last dissolves; that of the gall-bladder coagulates by acids and alcohol; that of the urine coagulates by tannin, but not by acids, is very soluble in alkalies, and dries red.

"The *adipose* are, besides the common fat, the medulla of the bones and grease of the skin.

"Related to these are the secretion of the corona glandis under the præputium, and of the external female genitals.

"The truly *serous*, or albuminous, are the fluid of the ovarian vesicle of De Graaf, and the liquor of the prostate.

"The *semen virile* and the *bile* are each *sui generis*." [b]

[b] Dr. Bostock arranges the productions of nutrition and secretion as the *aqueous*, *albuminous*, *mucous*, *gelatinous*, *fibrinous*, *oleaginous*, *resinous*, and *saline*. (*An Elementary System of Physiology*, vol. ii. p. 329. sq.)

The *aqueous* are the perspiration and pulmonary halitus, in which the proportion of water is so great as to give the chief character.

The *albuminous*, — all the membranous or white parts of animals, the fluids of serous membranes and of the cellular membrane, the former differing from the albumen of the blood chiefly in being freed from extraneous matter and coagulated; the latter from serum, chiefly in containing much less albumen.

The *mucous* are the mucus of all mucous membranes, the saliva, gastric juice, tears, and semen. The animal matter which is their basis much resembles coagulated albumen, and their salts are neutral, while those of the albuminous fluids are alkaline.

The *gelatinous* are named from containing jelly, — a substance not found in the blood nor any of the fluids, but abundantly in membranes, and particularly in the skin; and as albumen may be converted into it by digestion in dilute nitric acid, it appears to be the albumen of the blood with an addition of oxygen

Berzelius adopts the old division of secretions and excretions, and makes the following remarks: —

"There are two classes of secreted fluids, viz. the *secretions* properly so called, or the fluids intended to fulful some ulterior purpose in the animal economy, and the *excretions*, which are directly discharged from the body. The fluids of the former class are all alkaline, and of the latter all acid. The excretions are the urine, the perspired fluid, and the milk. All the other fluids appear to belong to the former class.

"The alkaline secreted fluids may be divided into two very distinct species. The former of these contains the same quantity

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and a diminished proportion of carbon. It abounds in the young, so that those parts, which at the beginning of life are almost entirely jelly, consist chiefly of albumen as age advances: since it is not found in the fluids, it must be supplied with its carbon again, and is, probably, reduced to the state of albumen. Dr. Prout considers gelatine the most imperfect form of albuminous matter — and the counterpart of the saccharine principle of vegetables.

The *fibrinous* are the muscular fibres, abounding in azote, and thus more completely animalised, resembling the fibrin of the blood, — apparently their source.

The *oleaginous* are the fat, marrow, and secretions of sebaceous glands, and perhaps the milk, as its properties depend so considerably upon oily matter.

The *resinous* are the bile, cerumen, and urea, very similar to the former, but owing their specific characters to a kind of resin. Osmazome is referred to this class; but what M. Raspail thinks of it was mentioned under the head of blood.

The *saline* are the acids, alkalies, and neutral and earthy salts of the various solids and fluids; generally more copious in the fluids than in the solids, absent in the simple oleaginous secretions, and abundant in the compound; and still more so in the resinous secretions. Their quantity is greatest in the bones, which are principally phosphate of lime; but, with this exception, the urine possesses the greatest proportion, as well as the most variety. 1. In some secretions they are absent; as the fat. 2. In some they exist in definite quantity, and this different from that in the blood; as the saliva. 3. In others, they are found in the same quantity, and of the same nature, as in the blood; such is the fluid of serous membranes. 4. In some, they are different from the salts of the blood, and of variable quantity; as the urea. These four divisions are — i. The solid and albuminous, the gelatinous, and simple oleaginous. ii. The mucous, fibrinous, compound oleaginous. iii. The liquid albuminous. iv. The aqueous and resinous.

This arrangement is certainly good; but, like every artificial arrangement of natural objects, convenient for general views and memory, rather than correct. For example, the semen is mucous, but unlike every other fluid: the gastric juice and cerebral substance are equally *sui generis*. Fibrinous matter as well as mucus exists in semen, and is probably, indeed, its specific part: albumen exists abundantly in milk, united into an emulsion with the oleaginous portion. The bile and urine have few properties in common; and urea is certainly not a resinous substance.

of water as the blood, so that the change induced by the nervous influence seems to be confined to that of altering the chemical form of the albuminous materials[c], without affecting their relative proportion to the water and other substances dissolved in the blood. The bile, spermatic fluid, &c. are of this kind. The latter species consists of fluids, in which the influence of the nervous system has separated a large portion of the albuminous matter, and left the remaining liquid proportionally watery. The saliva, the humours of the eye, and the effused serum of membranes are of this species; and in these the quantity of salts, and in general also of alkali, is the same as in the blood.

"The influence of the chemical agent of secretion is, therefore, chiefly spent upon the albuminous materials of the blood, which seem to be the source of every substance that peculiarly characterises each secretion, each of which is *sui generis*, and is its principal constituent. All the other parts of the secretion seem to be rather accidental, and to be found there only because they were contained in the blood out of which the secretion was formed. Therefore, in examining the secreted fluids, the chief attention should be paid to the peculiar matter of the fluid, which varies in all. This matter sometimes retains some of the properties of albumen; at other times, none; and hence an accurate analysis, showing the quantity and nature of this peculiar matter, is above all to be desired.

"If the several secretions be supposed to be deprived of their peculiar matter, and the remainders analysed, the same residue would be found from them all, which also would be identical with the fluid separated from the serum after its coagulation. Thus we should find, first, a portion soluble in alcohol, consisting of the muriates of potash and soda, lactate of soda, and of an extractive animal substance, precipitable by tannin; and, secondly, of a portion soluble only in water, containing soda (which acquires carbonic acid by evaporation, and is separable by acetic acid and alcohol) and another animal substance, not extract, precipitable from its solution in cold water, both by tannin and muriate of mercury. Sometimes a vestige of phosphate of soda will also be detected.

"The excretions are of a more compound nature. They all contain a free acid, which is termed lactic, and in the urine this

[c] This appellation Berzelius gives to the fibrin, albumen, and colouring matter of the blood.

is mixed with the uric acid. Urine seems to contain only a single peculiar characteristic matter; but milk has as many as three, viz. butter, curd, and sugar of milk, which, however, seem to be produced by different organs that mingle their fluids in the same receptacle. The perspired fluid appears to have no peculiar matter, but to be a very watery liquid, with hardly a vestige of the albumen of the blood, and, in short, is the same as the other excretory fluids would be when deprived of their peculiar matter. If we suppose this matter taken away from those excretions which possess it, the remaining fluid will be found to have properties very different from the fluid part of the secretions, when equally freed from their peculiar matter. That of the excretions is acid, contains earthy phosphates, and when evaporated, leaves a much larger residue than the fluid of the secretions. This residue is yellowish brown, of the consistence of syrup, with an unpleasant, sharp, saline taste of the salt that it contains. It reddens litmus, is most soluble in alcohol, and this spirituous solution contains the muriates of the blood, together with free lactic acid, much lactate of soda (the soda being the free alkali of the blood, neutralised by this acid), and the extractive matter, which always accompanies this neutral salt. The part insoluble in alcohol contains a distinguishable quantity of phosphate of soda, a little of a similar animal matter to that found in the secretions, and also the earthy phosphates which were held in solution by the lactic acid, and were precipitated by the action of the alcohol. The urine possesses also a number of other substances, which will be specified when describing this secretion in particular." [d]

The most simple mode of secretion is where the ordinary arteries in the neighbourhood ramify on a surface, as on the skin, mucous or serous membranes, and the fluid is poured forth *upon* it. The next mode is where the arteries ramify on the inner surface of a cup, called a cell or crypt, *into* which the fluid is poured, and in which it remains a longer or shorter time and becomes more consistent. The next is where this cup is so lengthened that it becomes a pouch or follicle. If prolonged still more, it is a canal, of various lengths. Next, what is termed a gland, is but a conglomeration of numerous canals, beginning each from a blind extremity and uniting together till they form one tube only, which opens upon some surface under the name of

[d] General Views of the Composition of Animal Fluids, by J. Berzelius, M.D. *Medico-Chirurgic. Trans.* vol. iii. p. 234.

excretory duct. Anatomists formerly supposed that the ducts of glands were, like veins, merely prolonged arteries, except, of course, where, as in the case of the liver, the secretion takes place by a vein. But Dr. Mueller, of Bonn, in a most elaborate work [e], in which he demonstrates this to be the structure of all glands in all animals, contends that the arteries ramify on the inner surface of the canals as upon any membranes, and, after forming a network, terminate in veins; so that the fluid secreted passes into the secretory ducts, which are in truth all excreting, just as we see it poured upon serous and synovial membranes. The excretory ducts of glands, therefore, precisely resemble the trachea, which divides and subdivides till it ends in blind twigs of extreme minuteness. Indeed, the extremities of the twigs of the ducts of the salivary glands of some animals are enlarged into a globular form, so that the woodcut which illustrates the air cells at the extremities of the bronchial twigs, might be taken for a delineation of the extremities of the salivary ducts of the sheep, for example, as may be seen in Dr. Mueller's sixth plate. Thus it would appear that all secretion is of that kind to which old physiologists gave the name of diapedesis or transudation, in which the fluid is supposed to be merely strained through the sides or open mouths of the vessels, and upon which Blumenbach remarks, that " physiologists have lately given different explanations of this mode of secretion. Some assert that every fluid is formed by passing merely through inorganic pores from the blood: others altogether deny the existence of these pores. I think much of this is a verbal dispute. Because, on the one hand, I cannot imagine how *inorganic* pores can be supposed to exist in an *organised* body, for we are not speaking here of the common interstices of matter, in physics denominated pores; and I am persuaded that every opening in organised bodies is of an organic nature, and possesses vital powers exactly correspondent. On the other hand, these openings or pores, which indisputably exist in the coats of vessels, I think but little different, in function at least, from the cylindrical ducts through which fluids are said to percolate in conglomerate glands and secreting viscera: for this percolation depends less on the *form* of the organ than on its *vital powers*." [f] But Dr. Mueller asserts that

[e] *De glandularum secernentium structura penitiori earumque prima formatione in homine atque animalibus.* Lipsiæ. 1830. folio.

[f] " Consult, among others, Schreger, *Fragmenta*, p. 37. sq. already recommended.

no openings exist; that the capillary blood-vessels, which form a network upon the inner surface of the secretory canals, do not secrete, but continue perfect canals till they become veins; and that the membrane itself, imbibing the blood and changing its fluid portions, pours this forth from its own substance upon its surface, and the secretion is performed not only at the extremities of the canal, but throughout it.

I agree, however, with those who believe that the new fluid is not formed by the substance of the walls of the canals, but passes formed from the minute twigs of the blood-vessels upon its surface; and I think, with Blumenbach, that the infinitely minute spaces, through which the fluid oozes into the secreting canals, must be regarded as living, not inorganic, pores. For, as I have already stated (p. 133.), the imbibition observable after death is not found to occur during life. In the next place, a secretion is not only increased by supplying the blood with more of the materials furnishing it, and vitiated by vitiating the blood, but may be rapidly and greatly augmented or altered without any augmentation or alteration of the materials in the vessels, merely by the administration of particular stimuli in minute quantity, or by emotions of the mind. Healthy secretion must be a living process, performed by living solids, and the minute spaces through which this secreted fluid moves, are spaces bounded by living solids, are apertures in living solids, and therefore not inorganic peres. Indeed, although it has been proved that glands are ducts beginning by blind extremities, and not prolonged from blood-vessels, and have their blood-vessels ramifying on their inner surface, I am not satisfied of the existence of proof that these blood-vessels transmit their fluid into the canal through apertures in their sides, and not by infinitely minute twigs with open mouths. As absorption takes place by the open mouths of vessels, secretion probably does the same. But whether these are mere apertures, or from these apertures the vessel is a little prolonged in the form of a minute twig, still the openings are in living solids, and therefore must be subject, like all the visible openings in the body, to the laws of life. If it is the

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P. Lupi, *Nova per poros inorganicos secretionum theoria refutata, &c.* Romæ, 1793. 2 vols. 8vo.

Kreysig, *Specimen Secundum*; formerly recommended.

Also C. Le Gallois, *Le sang est-il identique dans tous les vaisseaux qu' il parcourt?* Paris, 1802. 8vo."

substance of the sides of secreting canals that secretes, still it must secrete from fluid poured into it from blood-vessels. The contents of these vessels is blood. But it is not likely that blood oozes through the sides of its vessels, nor that the substance of a secreting canal has blood diffused in it. It is more likely that minute twigs arise from blood-vessels, and, being of a peculiar nature, admit only certain parts of the blood, which they change and transmit through open mouths into the secretory substance of the canal; or, that *living* openings exist in their sides that will permit the exit of only these certain portions of the blood, and these portions are poured forth into the substance of the sides of the secreting canal to be farther elaborated. But, on either supposition, the opening of the blood-vessel into its twig, or, if there be no twig, into the substance of the sides of the secreting canal, must have a living margin. Dr. Mueller, however, contends that the minutest streams of blood are contained in solids scarcely more dense than the blood itself, — in boundaries which are not vessels, but mere furrows, and so slightly different from the fluid blood, that this freely mingles with them and is changed into them or various new products. Unquestionably the minutest parts, and those which are the fundamental portion of the rest, are, like the embryo frame, of exquisite delicacy and softness. If we remark that the smallest artery of fins and webs may, under the microscope, be seen terminating in veins, and giving off minute vessels which run to veins, not colliquescing into a pulpy substance; we receive this reply, — that the minutest arteries must be pulpy enough to allow the blood to mingle with their substance. Yet the effect of emotions and certain articles is more explicable on the idea of organic openings and canals.

If Dr. Mueller is correct in supposing that the substance of the tubes secretes from *blood* poured into them, still I would contend that the blood passes into them through organic openings in the blood-vessels; and the fluid produced cannot pass from the substance through inorganic pores, because, being mixed with blood, or what is left of the blood, inorganic pores would transmit both. Again, what is left of the blood, after the separation of the new fluid from it, must be taken back, and we cannot suppose it to pass again through inorganic pores into the blood-vessels. Openings in them must have a power of selection, or the secreted fluid would equally pass back; and, if absorbents take up what is left, not mere organic *openings* but vessels are brought into play in the business; and vessels may as well be presumed to have also carried the secreted fluid from the blood. Indeed, that the secretion takes place in vessels, is proved, if an author is correct in asserting that the formation of the new substance within the vessels may be demonstrated "by forcing coloured injections into the arteries of growing bones, when the lime is seen to issue from their orifices in the form of a white powder, and deposit itself, like the farina of a flower, for the office of consolidation. In a similar way, the injected arteries of the common domestic hen, while her eggs are incomplete, will show the deposition of lime from their exhalant branches upon the membrane which afterwards becomes the shell." [g]

Some have thought no organic opening necessary, because the changes in the blood of the lungs take place through membrane. But the separation of carbonic acid is a mere physical or chemical occurrence, not a secretion, and takes place equally in dead blood, through dead membrane. The entrance of oxygen into the blood might be equally alleged as an argument against the existence of absorbent vessels on surfaces.

Just as solids are not originally firm, nor exactly of the nature they are when their texture is perfect, but the soft substance, which is their elementary portion, hardens by subsequent changes; so the fluids which pass from the blood-vessels are probably more and more changed, till they ooze perfect into the secreting canal. Even after this they become more consistent, as may be seen in mucus which has lain upon a mucous membrane, or the bile which has been in the gall-bladder.

The difference between nutrition and secretion is, that, in the former, the fluid does not pass away, but remains and coheres to the solids, and, undergoing further changes, solidifies, and becomes part of them.

The secreting surface of a gland must be very extensive. The blind extremities are of endless forms. Not only are some mere cups or crypts; some longer, so as to be pouches; some longer still, so as to resemble a portion of blind intestine; some, again, extremely long canals, of the same diameter throughout their course [h]: but any of these may be single or aggregated, and

[g] *A View of the Structure, &c. of the Stomach, &c.* By Thomas Hare, F.L.S. London, 1821. p. 77.

[h] "Malpighi, in works repeatedly quoted, and also in his *Diss. de glandulis conglobatis*, Lond. 1689, 4to, (but consult especially his *Opera Posthuma*, ib. 1697,

variously diversified, complicated, and arranged, and collected into a small space, so as to resemble vegetable forms, and be as various. These all consist of a single membrane, belonging to the class of the mucous; with some of which, indeed, it usually at last becomes continuous. When the conjunction of tubes has produced the portion called excretory duct, one or more additional coats unite with the essential membrane. The secreting membrane is always white, whitish grey, or whitish yellow, whatever the colour of the fluid secreted. Very different secretions are produced by glands of similar structure, as by the kidneys and testes; the same secretion is produced by very different structures in different animals, as the saliva, bile, urine, and semen. Some appear to require an immense surface to produce a given quantity; others one not of great extent. The secreting surface of the vessels, which by their union form the hepatic duct, must be immense: the gastric juice proceeds from the limited inner surface of the stomach; and this shows also that, for an important secretion, no gland, that is, no tube, or aggregation of tubes, is necessary. The saliva, on the other hand, is produced by several elaborately formed glands. Complexity of gland merely implies a greater extent of secreting surface; a larger number of canals being aggregated, or longer canals coiled up together. Amount of secreting surface is, of course, proportionate, not merely to the complexity of the tubes, but to the bulk of the whole organ.

The most elaborate fluids, as the semen, bile, urine, are produced by the most complicated glands, that is to say, such

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fol.; and published likewise elsewhere,) considered the miliary globules, which are easily discoverable in most glands, as acini, according to his expression, internally excavated," and having arteries open into them and excretory ducts begin from them to carry off the fluid first poured forth from the arteries and then fully elaborated in the acini. "Ruysch, on the contrary, contended that these supposed hollow acini were nothing more than glomerules of blood-vessels" which were continued into the excretory ducts. The acini are merely the blind extremities of ducts, and the blood-vessels, conglomerated into granules, as we saw when considering the liver. Duverney (*Comment. Ac. Sc. Petrop.* 1750.) showed that the lactiferous ducts of the hedgehog began as vesicles arranged like a bunch of grapes. Mascagni and Cruikshank afterwards demonstrated the same in the human breast, and Mascagni admitted that the excretory ducts began as blind extremities and had no arteries opening into them. He assumed the existence of inorganic pores. Dr. Mueller justly proposes to banish the term acini altogether, and speak only of the elementary parts of glands or blind beginnings of the secreting tubes.

fluids appear produced in small quantity from a given surface; and a fluid nearly aqueous, or at least with no peculiar constituent, is produced from so small a surface as that of a mucous or serous membrane, or crypts or follicles. Whatever may be the constituents of the fluid, if they are secreted with a large quantity of water, the complexity and bulk are not in proportion to the quantity of such secretion. For instance, the urine far exceeds the bile in quantity, yet the two kidneys together are not more conglomerated, and are smaller, than the liver; for the elaborate contents of the urine are greatly diluted with a fluid which requires no extent of surface for its production. I should, perhaps, say that the elaborate nature of a secretion, its amount, and its concentration, are all elements that require a more extensive secreting surface; and this is given by both complication and amount of canals, so that the relations of a secretion and the secreting organs depend not on one, but the whole, of these points. As a connection of peculiarity of secretion with peculiarity of structure cannot be discovered, the cause of such secretion must be certain unknown powers of the secreting organs, as inexplicable as the powers of formation and the powers of nutrition.

It is of no consequence, in the case at least of some organs, by what vessel the blood is conveyed to the secretory apparatus. Mr. Hodgson, on opening the body of a diabetic person, found the cavity of one renal artery obliterated by an accumulation of atheromatous and calcareous matter in its coats. The glandular structure was perfectly natural. The pelvis contained urine, and a considerable quantity of that fluid was found in the bladder. The kidney was supplied with blood by a large branch from one of the lumbar arteries and by the arteries of the renal capsule.[i] Dr. Andral once found a kidney in the pelvis, and supplied by the hypogastric artery.[k] When a breast which secreted good milk is situated on the thigh, we have another illustration of the same fact.

The quality of the blood, however, from which the part has to fabricate the new substance is important. The liver is supplied with venous blood as the material, and so are the kidneys of amphibia. We cannot suppose that arterial blood would have been suitable. For other secretions dark blood is unsuitable. Various

[i] *A Treatise on the Diseases of Arteries and Veins, &c.*

[k] *Précis d'Anat. Pathol.* t. ii. P. ii. p. 628.

secretions, and the quality of the solids of the body, are affected by the quality of the food and the absorption of different substances that alter the blood. Dr. Wollaston found the urine of birds to be nearly pure uric acid, if animal food only was taken.

If the kidneys refuse to secrete, urine may be found in the ventricles of the brain; and, when there was no outlet for it, an urinous fluid has been furnished by the stomach, intestines, or skin, &c.[l] In the latter cases, it may be said to have been fabricated by the kidneys and discharged by the other vessels, just as the pus of an abscess has sometimes been absorbed and discharged by the kidneys[m]: still we have the singular fact of vessels allowing to stream through them a fluid totally different from that which is natural to them.

On the other hand, the circumstance of secretions being frequently performed by vessels not destined or originally employed for their production, though the blood remains the same, shows how much depends upon the power of the part itself. Fat accumulates in diseased ovaria, and even the fleshy substance of the heart may be converted into it, as I once saw in a patient of my own. Bone is every day deposited between the inner and middle tunic of the arteries, and the serous membranes, or the subserous cellular membrane, continually ossified.

The bland mucus of the urethra may, by even mechanical irritation of the canal, be converted to a fœtid puriform fluid; the yellow bile and mild intestinal fluids to green, dark, scalding bile, and fœtid discharges, under the influence of acrid cathartics. Different animals and different plants require different sorts of food and soil, — external supplies; and produce different substances by nutrition and secretion under the same circumstances.[n] So that the requisites for a given production are two — materials and organic powers; and a change in either will occasion a change in the product.

[l] See examples in Haller's *El. Physiol.* l. vii. S. i. § ix. Several such have come to my own knowledge. Mr. Howship attended a lady who, he says, discharged many quarts of urine alternately from the bladder and rectum, after intervals of several weeks of suppression; and this for four years without serious injury. *Practical Treatise on Diseases of the Urinary Organs.* 1823.

[m] See Dr. Hennen's *Military Surgery;* and perhaps Heberden's *Commentarii,* p. 408.

[n] "If wheat and peas be sown in the same water, earth, or medium, the former will uniformly deposit silex in their cuticle, and the latter none." *Introduction to Botany,* by John Lindley, F.R.S. Prof. of Botany in the University of London, p. 233.

Though many constituents of secretions are not discoverable in the blood, some curious circumstances are related to show the importance of the qualities of the blood, as well as of the secretory organs, in producing peculiar substances. It is asserted that the blood will contain bile if secretion in the liver is prevented by tying the vena portæ; and urea appears in the blood, if the kidneys are removed, so that none can be secreted.[o]

In secretion the change must be chemical. Gelatine is merely decarbonised albumen; diabetic sugar is urea deprived of azote and some of its hydrogen; and the labours of Dr. Prout are displaying the various proximate principles of animals and vegetables to have the same elements, and to differ merely in the proportion of component water, or by the presence of a minute proportion of additional substance hitherto regarded as accidentally present and unimportant. Some substances, it is true, exist in vegetables and animals that cannot at present be entirely ascribed to external sources. Dr. Prout, from most careful experiments, concluded that there is strong reason to believe that the bones of the chick are not derived from the shell, but from internal production.[p] Vauquelin found the lime of the excrements of hens, and of the shell, to be too great to be ascribed to the food[q]; and the products of plants, fixed in sand and moistened with distilled water, contain so much more carbon and earthy matter than can be supposed to enter them from the atmosphere or the water, that Dr. Bostock and others of our best chemists conceive their existence inexplicable entirely upon these sources.[r] If such is the fact, we may conclude that these substances, though classed, as air and water once were, as elements, because not yet decomposed by chemists, are really not so; for creation by natural powers is impossible.[s] But, although secretion is, I apprehend, merely a chemical process, dependent upon the quality of the blood,

[o] Prevost and Dumas found that the removal of one kidney has no particular effect; but that the removal of both occasions copious vomiting and purging of brown liquid, and death; and 5 oz. of blood yielded ℈ i. of urea. *Annales de Chimie*, tom. xxii.

[p] *Phil. Trans.* 1822.

[q] *Annales de Chimie*, tom. xxix.

[r] See Dr. Bostock, l. c. vol. ii. p. 387. sq. Braconnot concludes that earths, alkalies, metals, sulphur, phosphorus, carbon, and perhaps azote, are thus produced. The immense quantities of calcareous strata, which appear to be the remains of marine animals, are thought referable to organic production only.

[s] Dr. John ascertained that some plants convert potass into soda.—Professor Lindley, l. c.

the chemical relations of the various particles, existing quite independently of life, and perhaps aided by the length and diameter of the vessels and other mechanical circumstances, are brought into play — circumstanced so as to become efficient — by the vital powers. How, we know not. But life cannot create any more than it can annul the physical or chemical qualities of matter; nor can it create matter. It may counteract one inanimate force by opposing to it another inanimate force; it may render one inanimate force efficient by withdrawing opponent inanimate forces. But this is all; how it accomplishes this, is yet unknown.

Secretion does not depend on the mind, though, like every function, much influenced by it. Fear *increases* the production of urine, rage *dries* up the mouth; any depressing passion will *vitiate* the milk. How far it depends upon nervous influence we shall consider when speaking of the nervous system.

"There is this difference among the various fluids secreted by the organs and powers now described, — that some pass to the place of their destination immediately, while others are deposited in receptacles, and detained there for a length of time, becoming more perfect before their excretion. The milk in its ducts, the urine, bile, and semen in their respective bladders, and in some degree the serum of the vesicles of De Graaf, are examples of this."

The more watery portion is absorbed, and therefore, the longer the stay in the ducts or receptacles, the more consistent does the fluid become. If the stay is considerable, the other portions also are absorbed, as seen in the case of jaundice from obstruction of the ductus hepaticus or choledochus. The detention of the urine is not for the purpose of perfecting it, but for convenience.

CHAP. XVI.

PERSPIRATION.

The skin is not only the organ of touch, but also, like the lungs, an organ of inhalation and excretion.

It "consists of three membranes:—The *corium*, internal; the *cuticle*, external; and the *reticulum*, intermediate.

"The *cuticle*, or epidermis [a], forms the external covering of the body, is separable into several lamellæ[b]," though it does not consist of imbricated scales[c], "and is exposed to the atmosphere, the contact of which can be borne by" no "other part, if you except" the hairs and nails, and the feathers, wool, horny hoofs, and claws of brutes, which are really of the same nature with it, and "the enamel of the teeth. For this reason, the internal cavities, and the canals which communicate with the surface for the purpose of admitting air, especially the respiratory passages and the alimentary canal," at least as far as the end of the œsophagus, "the tongue, the inside of the cheeks, the fauces, and the organ of smell, are covered by a fine epithelium, originating from the epidermis.[d]

"The texture of the epidermis is extremely simple, destitute of vessels, nerves, and true cellular membrane, and consequently" not organised; "very peculiar, however [e]; remarkably strong,

[a] "Al. Monro (Primus), Oratio *de Cuticula Humana*. Opera. English edition. Edin. 1781. 4to. p. 54. sq."

[b] "Among others, consult J. Mitchell, *Philos. Trans.*, vol. xliii. p. 111."

[c] Cloquet, *Manuel d'Anatomie descriptive*, p. 260.

[d] "Abr. Kaau, *Perspiratio dicta* Hippocrati, p. 7.

Lieberkühn, *De fabrica Villor. Intestin. Tenuium*, p. 16.

Cruikshank, *Expts. on the Insensible Perspiration*, p. 5.

Rudolphi, *Reisebemerkungen*, t. i. pp. 29. 140.

Jens. W. Neergaard, *Vergleichende Anat. der Verdauungswerkzeuge*, p. 21. et alibi.

J. B. Wilbrand, *Hautsystem in allen seinen Verzweigungen*, Giessen. 1813. 8vo."

[e] "The very dense epidermis of some immense animals consists of vertical fibres, which, in arrangement, somewhat resemble the structure of the Boletus igniarius. Its internal surface is porous, and penetrated by the silky filaments of the subjacent corium. This is remarkably exemplified in a preparation now before me, taken from the skin of the balæna mysticete.

considering its pellucidity and delicacy, so that it resists suppuration, maceration, and other modes of destruction, for a great length of time; and it is reproduced more easily than any other of the similar parts."

The cuticle separates during life by any irritant that causes a copious secretion below it; and by putrefaction after death, when the subjacent parts liquefy, and it retains its firmness. It is composed of gelatine and a cartilaginous substance like coagulated albumen, with perhaps a trace of salts of lime.

"It is" a kind of "horny lamella, and adheres to the subjacent *corium* by the intervention of a mucus, and by numerous very delicate fibrils which penetrate the latter.[f]

"The human cuticle, in certain diseased states, exhibits the same appearance as in the Englishman called the Porcupine Man, who laboured under a cutaneous complaint, which he transmitted to his children and grandchildren. Vide W. G. Tilesius, *Beschreibung und Abbildung der beiden sogenannten Stachelschwein-Menschen* (Porcupine Men). Altenb. 1802. fol.

"The innumerable polyhedrical papillæ and horny warts which I witnessed upon every part of the skin of these brothers, excepting the head, the palms of the hands, and the soles of the feet, bore some resemblance to the skin of the elephant, especially about the vertex and forehead of the animal."

One of this family exhibited himself a few years ago in Bond Street, and presented himself again lately at our schools of medicine. He was thirty years of age, and stated himself to belong to the fourth generation of the descendants of a savage who was found in the woods of America and had the same condition of skin. He informed me that it is transmitted to every male without exception in the male line, but has never appeared in the females or their male offspring: and that the horny warts first show themselves at two months from birth; are constantly growing, though most in summer; and are constantly being shed, but particularly in winter, till the thirty-sixth year, after which they are never shed, but continue to grow; so that in this man's father, who was eighty years of age, and lived in Suffolk when I saw the man, they were of very great length. They are set so close together, that their tops form a tolerably smooth surface, unless they are separated by extending the skin. Nearest those parts in which there are none, they gradually become smaller. Besides the parts mentioned by Blumenbach, the glans penis, I understood, was free from them. An arm of this family is well represented in Dr. Alibert's *Description des Maladies de la Peau*. See also *Ph. Tr.* 1731, for the first case known in the family.

"Similar, also, to the horny warts of this family are corns and the brawny cuticle of the feet in those who walk barefooted. Vide Carlisle on the Production and Nature of Corns, *Med. Facts and Observations*, vol. vii. p. 29."

[f] "W. Hunter, *Med. Observations and Inquiries*, vol. ii. p. 52. sq. tab. i. fig. 1, 2. The conjecture of this eminent man — that these fibrils are *vessels* which excrete the perspirable matter — is, I think, improbable."

Cloquet, however, says they appear to be exhalants and absorbents. l.c. ibid.

" The pores, which Leuwenhoek imagined in it," are not visible.

" The importance of the cuticle to organised systems is demonstrated by its universality in the animal and vegetable kingdoms, and by its being distinctly observable in the embryo from the third month at latest after conception."

The purpose of the cuticle is, 1. To cover the cutis like oiled silk, and preserve it moist and fit for its functions. Were the cutis exposed to the atmosphere, it would dry, and its vessels could neither excrete nor absorb, nor its nerves feel. This is partly seen, in regard to mucous membranes, when the uterus remains prolapsed beyond the opening of the vagina.[g] The protruded membrane of the vagina then becomes pale and shrivelled, like a dried bladder. The mucous membrane of the eyes and nostrils, and of the mouth, would dry up, but for the additional moisture supplied to the former by the lachrymal glands, and to the latter by the salivary; and so would the bronchial mucous membrane, if the air did not become first charged with moisture in passing through the mouth and nostrils, and if it passed through the bronchiæ instead of entering and returning. 2. To protect the cutis, thus preserved moist, from the immediate contact of substances; some of which would be too easily absorbed, and others would produce painful sensation.

" The inner part of the cuticle is lined by a fine mucous membrane, denominated, from the opinion of its discoverer, *reticulum Malpighianum*, and by means of which chiefly the cuticle is united more firmly to the corium.[h]

" Its nature is mucous; it is very soluble; and, being thicker in Ethiopians, may be completely separated in them from both the corium and cuticle, and made to appear as a true distinct membrane."[i]

[g] Skin and mucous membranes have much relation to each other; and by constant dryness of the latter, and constant moisture and excitement of the former, a great approximation may be effected.

[h] " Hence I have found the epidermis of *Albinoes* separate easily by the heat of the sun; whereas, in negroes, it scarcely does so on the application of a blister Consult Mitchell, l. c. p. 108."

[i] " B. S. Albinus, *De sede et causa coloris Æthiopum et cæteror. hominum.* Lugd. Batav. 1737. 4to. fig. 1.

Sam. Th. Soemmerring, *über die körperl. Verschiedenh. des Negers vom Europäer.* Ed. 2. p. 46. sq.

Some even of the moderns have assigned many laminæ, and even different

Dr. Gordon [k] and Mr. Lawrence [l] assert that they have never been able to detach any thing from the cutis of Europeans in the form of a distinct membrane; but the rete Malpighianum does exist in negroes, and the latter gentleman allows that the various complexions of Europeans and the peculiar cream white of the Albino, who has unquestionably no colouring matter in his eyes or skin, show that the substance exists even in us. Indeed, M. Gaultier considers that it has actually four layers: 1. An internal, composed of blood vessels; 2. One above this, of a white colour; 3. Another, composed of minute granules, which are brown in negroes and white in Europeans; and, 4. An external, also white, like the second. Some say that the black matter, as seen in negroes, when washed out, leaves a membrane and subsides to the bottom of the water, as a powder, and that it resembles the pigmentum of the eye and the matter of melanosis.

" Our colour resides in it. In all persons the corium is white, and, in almost all, the cuticle white and semipellucid, though in Ethiopians it inclines to grey. But the mucous reticulum varies after birth, with age, mode of life, and especially with difference of climate.

" Thus among the five varieties into which I would divide the human race, in the first, which may be termed Caucasian, and embraces Europeans (except the Laplanders and the rest of the Finnish race), the western Asiatics, and the northern Africans, it is more or less *white*.

" In the second or Mongolian, including the rest of the Asiatics (except the Malays of the peninsula beyond the Ganges), the Finnish races of the north of Europe, as the Laplanders, &c. and the tribes of Esquimaux widely diffused over the most northern parts of America, it is *yellow* or *resembling box-wood*.

" In the third or Ethiopian, to which the remainder of the Africans [m] belong, it is of a *tawny* or *jet black*.

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species, to the reticulum; as Lieutaud, *Essais Anatomiques*, p. 103. edition 1766.

Cruikshank, l. c. pp. 43. 99.

But especially G. A. Gualtier, *Recherches Anatomiques sur le Système cutané de l'Homme*. Paris, 1811. 4to."

[k] *System of Anatomy*, vol. i. p. 242.

[l] Rees's *Cyclopædia*, art. Integuments.

[m] " Jo. Nic. Pechlin, *De Habitu et Colore Æthiopum, qui vulgo et Nigritæ*. Kilon. 1677. 8vo.

Camper's oration on the same subject will be found in his *Kleiner Schriften*, vol. i. P. i. pp. 24—49."

"In the fourth or American, comprehending all the Americans excepting the Esquimaux, it is almost *copper coloured*, and in some of a *cinnamon*, and, as it were, *ferruginous*, hue.

"In the fifth or Malaic, in which I include the inhabitants of all the islands of the Pacific Ocean, and of the Philippine and Sunda, and those of the peninsula of Malaya, it is more or less brown, — between the hue of fresh mahogany and that of cloves or chestnuts.

"All these shades of colour, as well as the other characteristics of nations and individuals, run so insensibly into one another, that all division and classification of them must be more or less arbitrary.

"The essential cause of the colour of the Malpighian mucus is, if we mistake not, the proportion of carbon which is excreted together with hydrogen from the corium, and which, in dark nations, being very copious, is precipitated upon the mucus, and combined with it. [n]

"The *corium*, which is covered by the reticulum and epidermis, is a membrane investing the whole body, and defining its surface; tough; very extensible"; thicker on the posterior part of the trunk and neck than the anterior, and on the outside than the inside of the extremities; of a fibro-cellular texture; consisting almost entirely of gelatine; "every where closely compacted, and, as it were, interwoven, especially externally, but more loosely at its internal surface, in which, excepting in a few regions of the body, we generally discover fat." On the outer surface of the corium, we observe innumerable, very minute, soft, erectile papillæ, supplied with vessels and nerves. They are far most distinct in the soft part of the ends of the fingers and toes, and upon the palms and soles, and scarcely distinguishable in other parts where the corium is thinner.

"Besides *nerves* and *absorbents*, of which we shall speak here-

[n] "I have given this opinion at some length, in my work, *De Gen. Human. Varietate Nativa*, p. 122. sq. ed. 3. Some eminent chemists accord with me, among whom suffice it to mention the celebrated Humphry Davy, *Journals of the Royal Institution*, vol. ii. p. 30. '*In the rete mucosum of the African, the carbon becomes the predominant principle; hence the blackness of the negro.*' W. B. Johnson, l. c. vol. ii. p. 229.

F. B. Osiander has given an abundance of very careful observations upon the various proportions of the carbonaceous element in the Malpighian mucus. *Comment. Soc. Reg. Scientiar. Gotting. recentiorum*, vol. iv. p. 112. sqq."

after, innumerable blood-vessels penetrate to its external surface, upon which they are shown, by minute injection, to form very close and delicate networks.

"A vast number of *sebaceous follicles*," or bags with a single opening in their upper part and minute ramifications of blood-vessels on their interior, "also are dispersed throughout it" except the palms and soles, "and diffuse over the skin an oil, which is[o] very thin, limpid, does not easily dry,[p]" keeps the cuticle in a pliable state, and preserves it from any excessive operation of moisture, "is altogether distinct from the common sweat, and does not possess any odour" except in certain parts.

"Lastly, almost every part of the corium is beset with various kinds of *hairs*[q], chiefly short and delicate, more or less downy, and found nearly every where but on the palpebræ, penis, the palms of the hands, and soles of the feet. In some parts, they are long and destined for peculiar purposes; such are the capillamentum, the eye-brows, the eye-lashes, the vibrissæ, mustachios, beard, and the hair of the armpits and pudenda.

"Man is, generally speaking, less hairy than most other mammalia. But in this respect nations differ; for, not to mention those nations who to this day carefully pluck out their beard or the hair of other parts, others appear naturally destitute of hair, *v. c.* the Tunguses and Burats.[r] On the contrary, very

[o] "Chr. Gottl. Ludwig, *De Humore cutem inungente.* Lips. 1748. 4to."

[p] "Lyonet, *Lettre à M. Le Cat*, p. 12."

[q] "J. Ph. Withoff, *De pilo Humano.* Duisb. 1750. 4to. Compare the *Commentar. Societ. Scient. Gotting.* vol. ii.

Job. Baster, *Verhandel. der Maatsch. te Haarlem*, t. xiv. p. 382.

C. Asm. Rudolphi, *De pilorum structura.* Gryph. 1806. 4to."

[r] Dr. Wells describes the singular case of a man whose hair fell off throughout his body in about six weeks, without any evident cause or derangement of health, and did not return, except that about two years afterwards, while labouring under a suppurating tumour of the neck that discharged through several small holes, a fine down appeared upon his cheeks and chin, which occasioned him to shave once a week for about three months, when it disappeared. He always looked afterwards as if just shaved, and by wearing a wig would not have been noticed for any peculiar appearance. (*Transactions of a Society for the Improvement of Medical and Surgical Knowledge*, vol. ii.) Dr. P. Frank saw a similar case. (*De curandis hominum morbis*, t. iv. p. 124.) Another case will be found in the *Edinburgh Journal of Medical Science*, 1827. Morgagni mentions a man who had no hairs, except a few at the root of the penis, and yet whose genitals were well developed (*De Sedib. et Causis Morb.*, l. iii. Ep. 46.); Heister, a man who lost his hair without any obvious cause for ten years. Consult Dr. Otto's *Compend.*

credible travellers assert that some inhabitants of the Kurille and other islands in the Pacific and Indian Ocean are remarkably hairy." [s] But Krusenstern, a late circumnavigator, declares that he observed no particular hairiness of the people in this part of the world, and that former accounts are at least exaggerations.[t] In the island of Anicoa, he indeed met with one child, eight years of age, covered with hair; but such an instance has occurred in Europe. Zacchias, in 1613, saw a tall man at Rome covered with fine, long, straight hair, of a light yellow colour. There was a sister similarly hairy, and the father had been a hairy person, but the mother had not differed from other women. The man married; and, of four children, one girl and one boy were born covered with black hair, looking, says Zacchias, like black kids, and reminding the attendants of the account of Esau's birth: — "The first came out red, all over like a hairy garment." [u] In fifteen days the whole of this hair fell off; and, as puberty approached, soft fine hair sprung up all over the body, even over the temples and forehead.[x] Shenckius has collected several similar cases.[y]

Evelyn says, "On the 15th of August, 1657, I saw the hairy woman, 20 years old, whom I had before seen when a child. She was borne at Augsburg, in Germany. Her very eyebrowes were comb'd upwards, and all her forehead as thick and even as growes on any woman's head, neatly dress'd; a very long lock of haire out of each eare; she had also a most prolix beard, and mustachios, with long locks growing on the middle of her nose, like an Iceland dog exactly, the colour of a bright browne, fine as well-dress'd flax. She was now married, and told me she had one child

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of Path. Anat., translated by Mr. South, with additions, 8vo, Lond. 1831; where will be found abundant references to cases of most curious singularities of all the common integuments. Inflammation of the skin will make the hair fall off; as well as dirt, fever, pain of the head, the administration of mercury, and other causes of debility. They generally grow again, when the health is renovated, whether recourse is had to shaving or not.

[s] "*De Generis Human. Variet. Nativ.*, p. 29."

[t] *Voyage round the World.* Translated from the original German by G. B. Hoppner, vol. ii. p. 78.

[u] *Genesis*, c. xxv.

[x] *Quæstiones Medico-Legales*, lib. vii. Tit. 1. quæst. ix.

[y] Παρατηρήσιων, sive *Observ. &c. Volumen*, p. 778. sq.

that was not hairy, nor were any of her parents or relations. She was very well shap'd, and plaied well on the harpsichord," &c.[z]

"Nor is there less variety in the length, flexibility, colour, and disposition to curl, of the hair, both in each race of men enumerated above, and in individuals: *v. c.* the hair of the head in the Caucasian variety is rather dingy or of a nut brown, inclined on the one hand to yellow, and on the other to black; in the Mongolian and American, it is black, stiffer, straight and more sparing; in the Malay, black, soft, curling, thick, and abundant; in the Ethiopian, black and woolly: in individuals, especially of the Caucasian variety, there are great differences, and chiefly in connection with *temperament*, which is found intimately and invariably connected with the colour, abundance, disposition to curl, &c. of the hair[a]; and there also exists a remarkable correspondence between the colour of the hair and of the irides.

"The direction of the hairs is peculiar in certain parts, *v. c.* spiral on the summit of the head; diverging upwards on the pubes; on the exterior of the arm, as is commonly seen in some anthropomorphous apes (*v. c.* in the satyrus and troglodytes), running in two opposite directions towards the elbow, *i. e.* downwards from the shoulder, upwards from the wrist; to say nothing of the eye-lashes and eye-brows."

A hair consists of a bulb[b] and stem. The bulb or follicle, again, is ovoid, traverses the cutis obliquely, and consists of a capsular membrane, white, firm, and continuous at its outer extremity with the cutis, and of another internal, reddish, soft, delicate, and continuous with the rete mucosum. The cavity of the follicle is chiefly filled with a bud or conical papilla, adherent at its base to the bottom of the cavity, and free at its summit towards the

[z] Bray's *Memoirs of Evelyn*, vol. i. p. 307. 4to. 1819. In Granger's *Biography* an engraving and a mezzotinto of her are described. There is a curious engraving of her in the *Ephem. Nat. Curios.*, v. ii. obs. xcv. Her name was Barbara Van Beck.

[a] "Galen, *Ars Medicinalis*, pp. 211—235. M. Ant. Ulm, *Uterus Muliebris*, p. 128. et alibi, and Lavater, *Fragmente*, t. iv. p. 112., among many others."

[b] "I suspect that the bulb is intended for support rather than for nourishment, from this circumstance — that the locks of hairs sometimes found in meliccra and steatomata of the omentum and ovarium, some of which I have now before me, are usually destitute of bulbs, because they are not fixed, but lie naked in the honey-like fatty matter."

orifice of the follicle. On the exterior of the base of the follicles, filaments like roots are seen, and nerves and blood-vessels may be traced into it.

The stem is conoid, and proceeds from the interior of the bulb. Its base is hollow, and embraces the papilla; very soft, and even fluid where it is in contact with the papilla, which appears to secrete it. The rest is a horny, transparent, almost colourless sheath, and an internal coloured texture, consisting of very delicate filaments, and in some animals of an areolated texture.

The cuticle just enters the bulb, and is reflected and lost upon the surface of the stem. [c]

"The hairs are almost incorruptible, and always anointed by an oily halitus. Of all parts they appear most truly electrical. They are very easily nourished and even reproduced, unless where the skin is diseased."

They have been represented destitute of life. But they have turned permanently white in a single night from excessive copulation, and from fear and distress of mind.[d] In illness they often grow soft, and hang about the head. I know a lady whose hair will not keep in curl if she is in the slightest degree indisposed, and a young gentleman whose profuse curly hair becomes straight under the same circumstances: on the other hand, a case is recorded in which it always curled in a fit of the gout.[e] Hair taken from a dead body is said to be unfit for artificial use; it must be taken from the living: just as intestines taken from animals, not even diseased, but merely driven from a distance to the London markets, are said to be unfit for the strings of musical instruments. Shells are also considered destitute of life; but they cannot be rendered beautiful, I am told, if the fish dies of disease, or putrefies in them. Lastly, the hair has been so sensible in phrenitis after an injury, that the slightest touch gave severe pain; and when the surgeon clipped a hair unseen by the patient, this

[c] Cloquet, l. c.

[d] "My hair is grey, but not with years,
Nor grew it white in a single night,
As men's have grown from sudden fears."

Prisoner of Chillon.

See Byron's note to these lines, and Dr. Speranza in Dr. Omedei's *Annali Universali di Medicina.* Feb. 1832. Milan.

[e] *Quarterly Journal of Foreign Medicine,* No. xvii.

was instantly felt, and occasioned a paroxysm of rage.[f] Now sensibility cannot be acquired by a part not already alive.

Hair often grows abundantly in portions of the skin usually not much supplied with it, and these are generally of a brown colour: it will sometimes grow in parts naturally destitute of it, as the tongue and even the heart.[g] Sometimes it grows in encysted tumours, accompanied by fat, and occasionally by teeth and portions of jaw and amorphous bone; and feathers covered by fat are sometimes found in the thorax and abdomen of tame geese and ducks.[h] Hair has also been discharged from the urethra.[i] It has many times been seen blue as well as green.[k]

The skin produces *chemical changes* similar to those which occur in the lungs[l], and, like them, forms a watery *secretion*

[f] l. c. ibid.

[g] See references in Dr. Good's *Study of Medicine*, (4th edit.) vol. iv. p. 525.

[h] Blumenbach, *Comparative Anatomy*, § 138.

[i] *Phil. Trans.* abridg. vol. v. and ix.

[k] Various instances of both kinds in man and horse are collected by Dr. Speranza, l. c. Horses have had curly hair. Otto, l. c.

[l] "W. Bache, *On the Morbid Effects of Carbonic Acid Gas on Healthy Animals*. Philadel. 1794. 8vo. p. 46. Abernethy, l. c." Cruikshanks on *Insensible Perspiration*, and Ellis, *Further Inquiry on the Changes produced in Atmospheric Air*, &c. Others have questioned this, but no one doubts the fact in regard to cold-blooded animals. Dr. Edwards found the surface of frogs and salamanders to carbonise the air (l. c. p. 12.). Frogs are amphibious. They live indefinitely in extensive or renewed water, and die if it is de-aërated, or not changed (p. 41. sqq.); as also do aquatic salamanders and the common toad. If their lungs are removed, they still live indefinitely in such water or in air, and die if no air has access to their skin, or the water is not purified enough (p. 71.); and die sooner as they are younger and smaller. Although frogs live in air, mere respiration appears insufficient after a time; — some application of air or aërated water to the surface is also requisite to their life. That they live so long inclosed in wood or mineral substances, as is commonly known, appears owing to the opposition afforded, under these circumstances, to transpiration, which, in the open air, is so great as speedily to dry them up, while, at the same time, the closeness is not such as to entirely exclude air (p. 13.). They die in vacuo.

In a limited quantity of water, they die sooner the higher the temperature (p. 25. sqq.); and they support a high temperature better, if previously subjected for some time to a cold temperature (p. 33. sqq.). Although their skin be carefully moistened, they cannot live without respiration in summer (p. 91.). It appears from Dr. Edwards's experiments to be a general fact among animals, that the want of air is best borne in a low temperature. The general good effect of the application of cold in asphyxia by carbonic acid, is well known. The greater the external heat, on the contrary, the more is air required by the skin and

and excretes foreign matters, and is an organ of *absorption*.

The watery secretion is sometimes termed *perspirabile Sanctorianum*[m], after the patient and acute philosopher who first applied himself professedly to investigate its importance.

To ascertain the quantity of watery *secretion*, Lavoisier and Seguin[n] enclosed the body in a silk bag varnished with elastic gum and having a small opening carefully cemented around the mouth, so that, by weighing the body previously and subsequently to the experiment, they were able to ascertain exactly what had been lost, and, by subtracting from this loss the weight of the perspired contents of the bag, they also ascertained how much of this had passed off by the lungs. From repeated trials they found the mean pulmonary discharge in twenty-four hours amounted to

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lungs, independently, it would appear, of its chemical effect, as it is of use when there is no circulation, — when the heart is excised, either in frogs or cats, which perish after this operation the sooner as the temperature is higher. When the quantity of water, though limited, is sufficient to support life, the want of respiration causes the frogs to become as slow in their motions as turtles, and dull to all impressions on the senses (p. 65.). Lizards, serpents, and turtles, also carbonise the air by their surface; but serpents and turtles, and, indeed, some varieties of frogs, can live by respiration only, and this happens where the lungs of the animal are proportionally large (p. 128.). The effect of air, however, upon the surface, in reptiles at least, does not require the aid of circulation to distribute its benefits; for, when their heart is removed (and the same happens with toads, salamanders, and cats), they live much longer in air than in de-aërated water (p. 3. sqq.); yet they live longer if the heart is not removed (p. 7. sqq.).

m "*Ars* Sanctor. Sanctorii *de Statica Medicina aphorismor. sectionibus vii. comprehensa*. Venet. 1634. 16mo.

C. de Milly and Lavoisier, *Mémoires de l'Acad. des Sc. de Paris*. 1777. p. 221. sq. 360. sq.

J. Ingen-Housz, *Expts. upon Vegetables*. Lond. 1779. 8vo. p. 132. sqq.

J. H. Voight. *Versuch einer neuen Theorie des Feuers*, p. 157. sq."

"The balance employed by Sanctorius to estimate the loss of perspired matter is described in his *Comm. in* primam *Fen* primi *L. Canon*. Avicennæ. Venet. 1646. 4to. p. 781.

Another, much simpler and better adapted for the purpose, is described by Jo. Andr. Segner, *De Libra, qua sui quisque corporis pondus explorare posset*. Gotting. 1740. 4to.

J. A. Klindworth, an excellent Gottingen instrument-maker and engineer, altered this at my suggestion, and rendered it more convenient and accurate."

n *Mémoires de l'Academie des Sciences*, 1790.

15 oz., and the cutaneous to 30 oz. The quantity of carbon separated by the lungs ought however to be taken into the account. If it amount to 11 oz. in twenty-four hours,— the quantity stated by Allen and Pepys — there will be but 4 oz. of pulmonary exhalation. But if oxygen and azote are absorbed in respiration, there must have been correspondently more pulmonary exhalation; and we have seen that Hales estimated it at about 20 oz. in the twenty-four hours. They found the cutaneous transpiration at its minimum during and immediately after meals, and at its maximum during digestion.

The minimum after digestion was found by them to be 11 grs. per minute; the maximum 32 grs.: at and immediately after dinner $10\frac{2}{10}$; and the maximum $19\frac{1}{10}$, under the most favourable and unfavourable circumstances. It was increased by liquid, but not by solid, food. The pulmonary they regard as greater than the cutaneous, proportionally to the surface on which it occurs.[o] Whatever was taken, the weight was found to become ultimately as before. Indigestion lessened transpiration, and the body continued heavier generally till the fifth day, when the original weight was restored. Transpiration was less in moist air and at a low temperature, and the pulmonary and cutaneous transpirations obeyed the same laws.

Dr. Edwards has made a great number of experiments upon this subject.[p] He distinguishes the loss of fluid by evaporation of what is exuded, from that by secretion.[q] The former occurs even in the dead body, and is increased in both the dead and living, and among all animals, by the dryness, motion, and diminished pressure of the atmosphere. It may be suspended by saturating the air with moisture, and by employing animals (vertebrated, cold-blooded) whose temperature is not above that of the atmosphere; for, if those are employed whose temperature exceeds that of the atmosphere, the air as soon as it touches them is rarified, can take up more moisture, and is no longer air saturated with moisture. These circumstances, of course, affect only the removal or evaporation of fluid which may have either transuded or been secreted, but do not affect the secretion. In frogs,

[o] *Annales de Chimie*, t. xc.

[p] l. c. part iv. c. xi.

[q] He contends, however, that, in the lungs, all is evaporation without secretion. But, with Dr. Bostock, I must dissent from him.

which perspire copiously, the loss by evaporation at 68° is thus found six times greater than by mere secretion, and the proportion in man, the temperature being the same and the air dry, must be greater, as his skin secretes much less.

The secreted fluid may be carried off by evaporation as quickly as it is formed, so as to be insensible perspiration; or may be too abundant for this, and appear as sweat. The transuded fluid may also be condensed and precipitated on the skin in the form of sweat.

The cutaneous secretion is not so much augmented by moderate elevations of temperature as might be imagined; but, as the elevation proceeds, the augmentation of secretion becomes more than proportionate. It appeared increased after meals and during sleep, and, though subject to great fluctuations, if observed at short intervals, from accidental changes in the atmosphere, underwent successive diminutions when observed every six hours, from six o'clock A. M. — the hour of rising — till the return of the same period. In frogs this regular diminution might be detected every three hours.[r]

In frogs the cutaneous secretion continues, though at its minimum, in the moistest air and in water; and it would appear to do so also in man.[s]

The matter of the cutaneous secretion contains an acid, probably the acetic, chloride of potassium and sodium, acetate of soda, and perhaps albumen.[t] What evaporates is mere water.

Dr. Edwards makes some curious remarks upon the different effects of dry and moist air, when hot, and when cold. When hot, dry air will of course communicate less heat to the body than if moist, and will, by its dryness, cause more evaporation; and thus carry off more heat; so that the two operations of air, dry or moist, will correspond in temperatures above that of the body. When cold, dry air will remove less heat from the body than moist; but, by its dryness, will cause more evaporation, and therefore tend to cool more, so that the two operations oppose each other in temperatures inferior to that of the body.[u] The same remarks apply to cold water.

[r] For what relates to this function in the batrachians, see l. c. part i. c. v. and vi.

[s] p. 92. sqq. 98. sqq. 351. sqq.

[t] Berzelius, *Animal Chemistry*, p. 95.

[u] l. c. p. 386. sq.

He did not find moist cold air to cool animals more than dry cold air.

In low temperatures, we have seen that the loss by evaporation greatly exceeds that by secretion. In high, it is the reverse; and, when the body is covered with sweat, there can be no loss by the evaporation which occurs, independent of secreted fluid, whether the air be dry or moist. Vapour will cause more loss by secretion than dry air; but no loss can take place by the lungs in hot vapour.[x]

Perspiration can never be entirely suppressed; because the cold which suppresses secretion, causes the air, however moist, and therefore opposed to evaporation, to rise in temperature, by coming in contact with the body; and the superior temperature which it instantly acquires, enables it to hold more moisture, and evaporation from the skin is thus instantly promoted.[y]

There is a common belief, that the cutaneous exhalation has always peculiar properties, invigorating in the young, and debilitating in the old. David lay between two young girls to gain strength; and Dr. Copland declares he has seen a child suffer from lying with its grandmother.[z]

The elimination of foreign matters by the skin is shewn by the odour of the perspiration after some odorous substances have been taken, by its effect upon silver when mercury is prescribed, and by its green and coppery secretion when copper has been introduced.[a]

The odour of the secretion of the sebaceous follicles, and that of the perspiration, are, in some parts, naturally peculiar, and in different persons more or less intense, and even singular; and either always, only under excitement, or only at times when under excitement, in different parts. In the tonsils,

[x] p. 380. sq. [y] p. 335. sq.

[z] *Dictionary of Practical Medicine*, by James Copland, M.D., art. DEBILITY. A work displaying such extraordinary extent of reading, and such deep and comprehensive reflection, as to demand a place in the library of every medical man.

[a] See a case in the *Lond. Med. Gazette*, Nov. 19. 1832.

" Hence the danger of contagion from hairs, as miasmata adhere to them very tenaciously for a great length of time. Vide Cartwright, *Journal of Transactions on the Coast of Labrador*, vol. i. p. 273. vol. ii. p. 424."

" G. Wedemeyer, *Historia Pathologica Pilorum* (honoured with the royal prize). Gotting. 1812. 4to."

when the secretion is solid, it is horridly offensive, really fæcal, and is a frequent cause of fœtid breath: in the glands behind the ears, when the secretion is squeezed out in a solid form, its smell is said to be caseous: in the parts of generation, saline and peculiar. In many brutes, the odour of the female genitals attracts the male, and is strongest when the animal is in heat. All know that the mere sweat has a different smell in different parts; in the arm-pits, hircine; in the feet, sometimes like that of tan, and sometimes of cabbage-water. If the palms of the hands of some persons are rubbed briskly together, an odour something like that of hot boiled potatoes is evolved; in others general excitement of the system occasions this. A sulphureous odour, which perhaps was not very dissimilar, is said, in the *Ephemerides*, to have proceeded from Cardan's arm; from the head of a boy at Rome; and from a dropsical boy.[b] Schmidt mentions a man from whose hands and arms an intolerable fœtor of sulphur proceeded.[c] Egesandro mentions two persons so offensive that they were not allowed to visit the public baths.[d] In the same volume of the *Ephemerides* we read of a literary man whose stench was far too much for all perfumes; and Hagendorn declares he saw a woman who was unbearable at the distance of some feet, — a second Thais.[e] In America the shrew spreads a horrid stench to escape its pursuers; and the yellow serpent of Martinique is known by its fœtor to be present. Persons differ not only in the amount of their general perspiration, but in its amount in different parts; and under exercise and heat different

[b] *Ephem. Nat. Curios.* ann. ii. p. 191.

[c] *Ephem.*, ann. viii. Dec. 2.

[d] *Giornale Venet.* t. ii. See Dr. Speranza, l. c. p. 241.

[e] Tam male Thais olet, quam non fullonis avari
Testa vetus, media sed modo fracta via;
Non ab amore recens hircus; non ora leonis;
Non detracta cani Transtiberina cutis;
Pullus abortivo nec quum putrescat in ovo:
Amphora corrupto nec vitiata garo.
Virus ut hoc alio fallax permutat odore
Deposita quoties balnea veste petit;
Psilothro viret, aut acida latet oblita creta:
Aut tegitur pingui terque quaterque faba.
Quum bene se tutam per fraudes mille putes?
Omnia quum fecit, Thaida Thais olet.

Mart. l. vi. ep. 93.

persons sweat most in different parts. Now a person, from merely happening to sweat most in a part, the secretion of which is generally offensive, may probably acquire the characteristic odour, without having a particular disposition to filthiness of secretion. The general perspiration of every one probably smells peculiarly, for savages can distinguish the nation of persons by the smell.[e] (Haller and Humboldt.) The boy born deaf and blind, whose history is related by Mr. Dugald Stewart, distinguished people by their odour; and I once saw, in the report of a trial in the newspapers, that dealers in hair boasted of being able to tell the nation from which the hair came, merely by the smell. The power possessed by brutes in distinguishing and tracing us and other animals is well known; and we perceive the various odours of many brutes, especially if they perspire freely and are numerous. The odour of a dog-kennel on the one hand, and of a heated flock of sheep in the road, must be known to every one. No doubt every animal and vegetable, like all inanimate matter, exhales a peculiar odour, cognisable to organs which are of sufficient acuteness and not blunted by habitual exposure to it.

In different diseases the odour of the perspiration is often peculiar; and the admission of certain substances into the system, that escape by the pulmonary and cutaneous secretions, will necessarily give them an odour.[f] Some odours of animals are most intense during sexual heat.

The odour of some persons is said to have been quite a perfume. Plutarch mentions that Alexander the Great smelt, not of carnage like a hero, but most pleasantly. Fragrance proceeded also from Augustus.[g] In the memoirs of the Queen of Navarre we read that Catherine de' Medici was a nosegay; and Cujacius

[e] "Fr. L. Andr. Koeler, *De Odore per cutem spirante in statu sano ac morboso.* Gotting. 1794. 4to."

[f] ——— Elevés dans Paris,
Sentent encore le chou dont ils furent nourris.
MOLIÈRE.

[g] Since both these were worshipped as gods we cannot wonder at the thing; for the most elegant of the gods and goddesses had all this attribute. Diana was recognised by Hippolytus from her divine odour,

——— Ὦ θεῖον ὀδμῆς πνεῦμα —
. . . . .
Ἐστ' ἐν δόμοισι τοῖσδέ γ' Ἄρτεμις θεά;
EURIPIDES, *Hippolytus*, 1391.

the civilian, and Lord Herbert of Cherbury, were equally delightful. Dr. Speranza lately witnessed a strong balsamic fragrance from the inner part of the left forearm of a healthy man, which continued, especially in the morning, for two months, and ceased for good on the supervention of fever.[i] Van Swieten mentions a man whose left armpit smelt strongly of musk; and Wedel and Gahrliess saw each a similar example.[k]

Absorption by the skin, unless friction is employed or the cuticle abraded, has been denied. We are told that Dr. Currie's patient, labouring under dysphagia seated in the œsophagus, always found his thirst relieved by bathing, but never acquired the least additional weight[l]: that Dr. Gerard's diabetic patient weighed no more after cold or warm bathing than previously[m]: that Seguin found no mercurial effects from bathing a person in a mercurial solution, provided the cuticle remained entire; while they occurred when the cuticle was abraded.[n]

But the two former cases are no proofs that water was not absorbed, because the persons immersed did not lose in weight, which they would have done if not immersed, owing to the pulmonary and cutaneous excretions; these therefore must have been counterbalanced by absorption somewhere, and no shadow of proof can be urged against its occurrence by the skin, as Dr. Kellie remarks in his excellent paper on the functions of this part.[o] Seguin besides found two grains of the mercurial salt disappear in an hour from the solution when of the temperature of 72½°.

There is every reason to believe the occurrence of cutaneous absorption independently of friction or abrasion of the cuticle. First, the existence of absorbents all over the surface cannot be intended for use merely when friction is employed or the cuticle

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When Venus showed herself to her son,

> Ambrosiæque comæ divinum vertice odorem
> Spiravere. *Æneid.* i. 403.

Homer says the same of Venus (*Odyss.* θ), and of Juno (*Iliad*, ξ. 170. sqq.). Flora, Ceres, and Apollo also were nosegays.— Ovid, *Fast.* v.; Homer, *Hymn. in Cererem.*

[i] *Annali universali di Medicina*, Feb. 1832.

[k] *Ib.* Where three other cases of fragrance are referred to, in two of which it proceeded from the hands; as well as singular examples from among brutes.

[l] *Medical Reports, &c.*

[m] Rollo, *On Diabetes.*

[n] *La Médecine éclairée, &c.* t. 3.

[o] *Edinburgh Med. and Surg. Journal*, vol. i.

abraded. So numerous are its absorbents, that, when successfully injected with mercury, the whole surface looks like a sheet of silver.[p] Secondly, we have many facts which prove absorption without these circumstances, either by the skin or lungs, or both, while no reason can be given why they should be attributed solely to the lungs. A boy at Newmarket, who had been greatly reduced before a race, was found to have gained 30 oz. in weight during an hour, in which time he had only half a glass of wine.[q] Dr. Home, after being fatigued and going to bed supperless, gained 2 oz. in weight before seven in the morning.[q] In three diabetic patients of Dr. Bardsley's, the amount of the urine exceeded that of the ingesta, and the body even increased in weight, and in one of the instances as much as 17 lbs.[r] Dr. Currie allows that, in his patient, "The egesta exceeded the ingesta in a proportion much greater than the waste of his body will explain; and, indeed, such facts occur every day." The same patient's urine, too, after the daily use of the bath, flowed more abundantly and became less pungent. Keill says that he one night gained 18 oz. in his sleep: and Lining, that, after drinking some punch one cool day, "the quantity of humid particles attracted by his skin exceeded the quantity perspired in these two hours and a half by $8\frac{1}{3}$ oz.," and gives two more such instances in the same table.[s] Dr. Edwards observed similar facts in guinea-pigs. Thirdly,[t] we have positive evidence of cutaneous absorption without friction or abrasion, in the case of frogs, toads, nay, in scaly lizards, which will increase in weight by cutaneous absorption, even if only a part of them is immersed in water; and remarkably so if previously made to lose much of their moisture by exposure to the air[u], although they never surpass the point from which the loss of weight began.[v] The increase is much greater in water than in the moistest air.[x] Dr. Beaupré says, that, if a new born puppy is held a quarter of an hour in warm ink, the urine subsequently made is coloured.[y]

[p] Dr. Gordon, *Anatomy*, p. 234.

[q] Bishop Watson, *Chemical Essays*, vol. iii. p. 101.

[r] *Medical Facts and Experiments.*

[s] *Phil. Trans.* vol. xlii. p. 496.

[t] l. c. p. 362.

[u] Dr. Edwards, l. c. part iv. ch. xii.

[v] l. c. p. 101.

[x] l. c. p. 360.

[y] *A Treatise on the Effects and Properties of Cold*, by M. Beaupré, M.D., translated, with notes, by Dr. Clendinning. Edin. 1826. p. 56.

In all the cases which have been mentioned, there is no reason to suppose that exhalation did not continue, both on the skin and in the lungs, so that the absorption must have been greater than it at first sight appears. When no increase of weight has taken place on immersion in the warm bath, absorption must have occurred to maintain the weight, notwithstanding the cutaneous and pulmonary losses; and, when some decrease of weight has been observed, we are not justified in concluding that absorption had not taken place and not lessened the amount of the loss which would have happened. Indeed, there is no doubt that perspiration is considerably increased in the warm bath. — I may remark that, while absorption is more active accordingly as more fluid has been lost, it gradually becomes less as it approaches the habitual standard of plenitude in the individual, and that, while transpiration is increased by elevation, the proportion of absorption is increased by depression of temperature.[z]

Dr. Massy, of America, about 1812, found that, if the body were immersed in a decoction of madder, this substance became discoverable in the urine by the alkalies; and Dr. Rousseau, in conjunction with Dr. S. B. Smith, made, in consequence, a number of experiments, from which they conclude that rhubarb and madder are so absorbed, and that these only of all absorbed substances can be discovered in the urine, and are seen in this fluid only, and are absorbed by no other parts than the spaces between the middle of the thigh and hip, and between the middle of the arm and shoulder.[a]

[z] l. c. p. 98. sqq. 352. sqq.

[a] *Discourses on the Elements of Therapeutics and Mat. Med.* 1817. vol. i. p. 56. sq.

Vegetables perspire copiously during the day; not so much according to the temperature, but to the intensity of light; and De Candolle found that lamps had a similar power on the function to that of the solar ray, and proportionately to their intensity. (*Physiologie Végétale*, t. i. p. 112.) The number of pores or stomata through which the fluid exhales, will also influence its quantity. Hales inferred that a sunflower, three feet high, exhaled only twenty ounces, — seventeen times more, according to him, than would have been perspired from an equal extent of the human surface. Generally the sap loses about two thirds of its water, and the exhaled portion is probably pure, or does not contain more than a 10,000,000th part of the foreign matter which it had when first absorbed. (Dr. Roget, *Bridgewater Treatise*, vol. ii. p. 27. sq.)

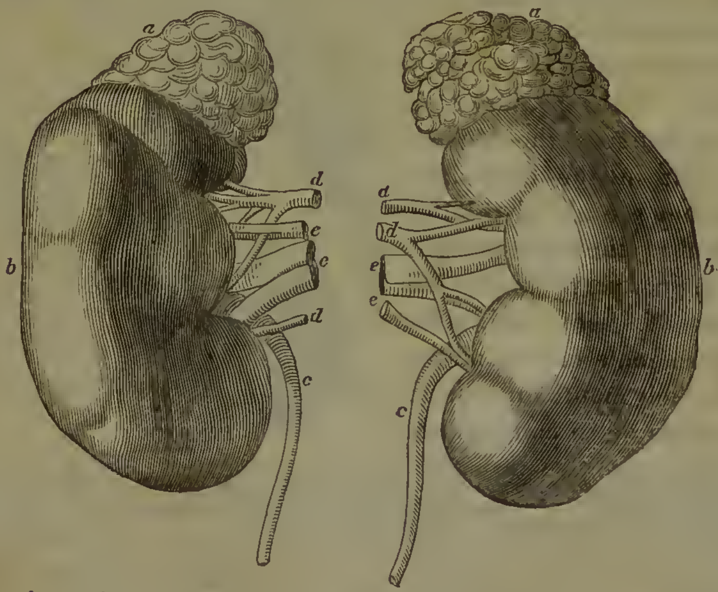
The greater number of cellular plants absorb water equally at every part of their surface. Lichens only in particular parts. In vesicular plants the surface absorbs but little, except when the roots have been removed, or can obtain no water.

CHAP. XVII.

THE URINE.

There is another fluid incessantly secreted, and always discharged from the body, that serves no direct purpose, like the bile or saliva, — is not *recrementitious;* nor indirect purpose, like the perspiration, which regulates our temperature and preserves the skin in a fit and healthy state; but is purely *excrementitious.* It is the *urine,* and is produced by the kidneys.

"The kidneys[a] are two viscera, situated at the upper part of the loins on each side, behind the peritonæum; rather flattened; more liable than any other organ to varieties of figure and number[b];" connected with the aorta and vena cava inferior by the



a, renal capsule. *b,* kidney. *c,* ureter. *d,* branches of renal vein. *e,* branches of renal artery.

[a] "See Al. Schumlansky, l. c."

[b] "See Jer. Blasius, *Renum monstrosorum exempla,* at the end of Bellini, *de structura et usu renum.* Amstel. 1665. 12mo."

renal artery and vein [c], "which are excessively large in proportion to them; and imbedded in sebaceous fat.

"They are enveloped in a membrane of their own, which is beautifully vascular; and each, especially during infancy, consists of eight, or rather more, smaller kidneys, each of which again consists, as Ferrein asserted, of seventy or eighty fleshy radii, denominated by him pyramides albidæ.

"A kidney, if divided horizontally, presents two substances; the exterior, called *cortex;* the interior, *medulla.*[d]

"Each abounds in blood-vessels; but the cortical portion has likewise very minute colourless tubes which "are the origins of the uriniferous ducts [e]; the medullary part contains these ducts. The blood-vessels are distributed in rather a reticulated manner among the tubes, with which they have no communication of canal. Small round hollow bodies are also seen, containing blood, and connected with the blood-vessels, but with them only.[f]

"These tubes arise, in the manner formerly described" in regard to the bile ducts, from minute blind extremities, not dilated, but nearly of the same diameter as the rest of the canal, and "formed in the cortical part; of which they constitute the greatest portion." They preserve an angular course in the cortica part; but in the medullary, where they are called the Bellinian tubes, they run straight. The cortical part "principally consists of them; and, after they have coalesced into fewer trunks, their mouths perforate, in the form of so many cones,

a, cortical part.
b, medullary.
c, papillæ.
d, infundibula.
e, pelvis.
f, ureter.

[c] "Eustachius, *tabulæ,* i.—v., which belong to his classical work *De renibus* published with this great man's other *Opusc. anatom.* Venet. 1564. 4to. Also tab. xii."

[d] "C. W. Eysenhardt, *De structura renum Observationes Microscopicæ.* Berol. 1818. 4to."

[e] "These appear to have imposed upon Ferrein as a new description of vessels which he called neuro-lymphatics, or white tubes, and of which he imagined the whole parenchyma of the viscera to be composed. He affirmed that they were of such tenuity, that their length in each kidney of an adult man was equal to 1000 orgyiæ (60,000 feet) or five leagues."

[f] Mueller, *De glandularum secernentium, &c.* p. 102.

like a sieve, the *papillæ* of the pelvis of the organ [g]," or, more properly, the rounded ends of these cones project as so many papillæ.

"These papillæ usually correspond in number with the lobes which form the kidneys, and they convey the urine, secreted in the colourless vessels of the cortex and" "the Bellinian tubes of the medulla, into the *infundibula*," or little membranous canals which at one end surround the duct or papilla, and at the other "unite into a common *pelvis*.

"The pelvis is continued into the *ureters*, which are membranous canals, very sensible, lined with mucus, extremely dilatable, generally of unequal size in the human subject in different parts [h], and inserted into the posterior and inferior surface of the bladder in such a way, that they do not immediately perforate its substance, but pass a short distance between the muscular and cellular coats, which at that part are rather thicker than elsewhere, and finally open into its cavity by an oblique mouth. This peculiarity of structure prevents the urine from regurgitating into the ureters from the bladder."

As the ureters have a tendency to lose this obliquity of inscrtion in proportion as the bladder is depleted, two long bands of muscular fibres run from the back of the prostate gland to the orifices of the ureters, and not only assist in emptying the bladder, but, at the same time, pull down the orifices of the ureters, and thus tend to preserve the obliquity.[i] When the bladder is distended, and the urine flows with difficulty into it, the fluid accumulates in the ureters, and, as the obliquity greatly lessens as soon as the bladder is emptied, the urine then flows freely into it, and persons, after making a large quantity of urine, thus very soon make another quantity.

"The urinary *bladder* [k]," oviform in the adult, but "varying in shape according to age and sex, is generally capable, in the adult, of containing two pints of urine. Its fundus, which in the fœtus terminates in the urachus, is covered posteriorly by the peritonæum. The other coats correspond with those of the stomach.

"The *muscular* consists of interrupted bands of fleshy fibres,

[g] "Eustachius, tab. xi. fig. 10."

[h] "See Nuck, *Adenographia*, fig. 32. 34, 35. Leop. M. Ant. Caldani, *Saggi dell' Accad. di Padova*, t. ii. p. 2."

[i] Sir C. Bell, *Med. Chir. Trans.* vol. iii.

[k] "Duverney, *Œuvres anatomiques*, vol. ii. tab. i.—iv"

variously decussated, and surrounding the bladder.[l] These are called the detrusor urinæ: the fibres which imperfectly surround the neck, and are inconstant in origin and figure, have received the appellation of sphincter.

" The *cellular* chiefly imparts tone to this membranous viscus.

" The *interior*, abounding in cribriform follicles [m], is lined with mucus, principally about the cervix.

" The urine conveyed to the bladder gradually becomes unpleasant by its quantity, and urges us to discharge it. For this purpose the *urethra* is given, which " is a canal beginning at the lowest part of the bladder, much longer in the male than the female, and attached to the arch of the pubes by muscular fibres that are described by Mr. Wilson under the name of compressor urethræ and conceived to act as the sphincter of the bladder, " varies with the sex, and will be farther considered in our account of the sexual functions.

" The bladder is evacuated from the constriction of the sphincter being overcome both by the action of the detrusor and by the pressure of the abdomen." The assistance of the abdominal muscles, however, is not absolutely requisite, however greatly it may contribute; because, if we keep them motionless, and direct our attention to the bladder, when it contains urine, a sensation is immediately felt at its neck; and if we still fix our attention, we can will the passage of the urine through it, probably by willing a relaxation of the muscular fibres of the part, as much as by willing a contraction of the detrusores fibres, — the diaphragm and abdominal muscles being still preserved motionless. " The last drops of urine remaining in the bulb of the" male " urethra are sent forth by the ejaculatores seminis.

" The nature of the *urine* varies infinitely [n] from age, season of the year, and especially from the length of the period since food or drink was last taken, and also from the quality of the

l " Santorini's posthumous tables, xv."

m " Flor. Caldani, *Opus. anat.* Patav. 1803. 4to. p. 4."

n " See Hallé, *Mém. de la Soc. de Médecine*, vol. iii. p. 469. sq."

o " The specific quality of some ingesta manifest themselves in the urine so suddenly, even while blood drawn from a vein discovers no sign of their presence, that philologists have thought there must be some secret ways leading directly from the alimentary canal to the kidneys, besides the common channels. An examination of them will be found in Aug. H. L. Westrumb's Commentary (honoured with the royal prize) *de phenomenis, quæ ad vias sic dictas lotii clandestinas demonstrandas referuntur.* Gotting. 1819. 4to., and P. G. C. E. Bark-ingesta[o], &c. The urine of a healthy adult, recently made after a tranquil reposc, is gencrally a" clear " watery fluid of a nidorous smcll" while warm, "and of a lemon" or amber " colour," saline, bitter, and disagreeablc to the taste, " and contains a variety of matters[p] held by a large quantity of water in solution, and diffcring" in their absolute quantity in different persons, and in thc same person at different times.

The more aqueous fluid is taken, and the less the skin and lungs secrete, as in cold weather, the larger the amount of water in the urine, which is then paler, more copious, and lighter. The opposite circumstances, as well as exercise or feverishness, render it high coloured, scanty, and heavy. Its usual specific gravity is from 1015 to 1025. Much of the matters dissolved subside in the form of a pale brown or reddish sediment after it has stood, if the individual is feverish or dyspeptic, and the temperature to which it is exposed is low; and they dissolve again if it is warmed. The quantity made daily by adults in health, though much influenced by the quantity of liquids drunk, is, perhaps, on the average, about three pints in the twenty-four hours. After standing some time, the urine, which, when first made in health, is acid, becomes alkaline, emits a strong ammoniacal smell, and is covered with a white mucous pellicle, in which, as well as on the sides of the vessel, crystalline phosphate of magnesia and ammonia is seen: yellow cubic crystals of chloride of ammonia are then deposited, next yellow octohedrons of chloride of ammonia, and lastly microcosmic salt or the fusible salt of the urine,—phosphate of magnesia and ammonia. The fluid in the mean time becomes a brown and fœtid syrup.

The following is Berzelius's analysis of urine, in 1809[q]:—

Watcr - - - -	933·00
Uric acid - - - -	1·00

hausen's Dissertation (which gained the second prize) *dc viis clandestinis urinæ.* Berol. 1820. 8vo."

Sir Everard Home observed, in his experiments on the spleen, that colouring matters began to manifest themselves in the urine about seventeen minutes after they were swallowed, became gradually more evident, then gradually disappeared, and after some hours, when the mass had unquestionably passed into the intestines, again tinged it as strongly as ever.

[p] See Fr. Stromeyer, *Theoret. chimie,* t. ii. p. 609.

[q] *Med. Chir. Trans.* vol. iii.

Urea - - - -	30·10
Sulphate of potass - - -	3·71
Sulphate of soda - - -	3·16
Phosphate of soda - - -	2·94
Chloride of sodium - - -	4·45
Phosphate of ammonia - - -	1·65
Chloride of ammonia - - -	1·50
Free lactic acid - - -	17·14
Lactate of ammonia - - -	
Animal (extractive) matter soluble in (anhydrous) alcohol, and usnally accompanying the lactates - - -	
Animal matter insoluble in alcohol -	
Urea, not separable from the preceding -	
Earthy phosphates with a trace of fluate of lime	1·00
Mucus of the bladder - -	0·34
Silex - - - - -	0·03
	1000·00

In the urine of young children and herbivorous animals benzoic acid is found, united with animal matter, and perhaps thus exists as a peculiar acid, for which Berzelius proposes the name of uro-benzoic acid.[r]

According to some, urine, like the blood, affords carbonic acid gas under the receiver of an air-pump[s], and more after a meal[t]; but others regard its presence as accidental, from not having been able to find it.[u]

Uric acid is in the form of soft white scales, without taste or smell, requiring a thousand times its weight of cold water for its solution, and nearly as much of boiling water. According to Dr. Prout it consists of

Nitrogen - - -	31·125
Carbon - - -	39·875
Hydrogen - - -	2·225
Oxygen - - -	26·775

The urine contains much more uric acid in solution than an equal quantity of boiling water would dissolve. Hence Dr. Prout con-

[r] *Traité de Chimie*, t. vii. p. 363. 1833.
[s] Vogel, *Annales de Chimie*, t. xciii.
[t] Mr. Brande, *Phil. Trans.* 1810.
[u] Berzelius, l. c. and Whoeler.

ceives that it is in the state of urate of ammonia, which is decomposed by the other acids when it cools: while others fancy that the solution in the urine of substances so little soluble is a fact analogous to that of iodine being so much more soluble in water charged with chloride of sodium or ammonia.

Urea is in the form of slender four-sided prisms, colourless, inodorous, and deliquescent, and affords a cool taste like nitre: it reacts as neither an acid nor an alkali.

It is a common mistake, even at present, to ascribe the colour and smell of urine to it. Whoeler has shown that urea is a cyanite of ammonia. Dr. Prout has established that it consists of

Hydrogen - -	·266
Carbon - - -	·799
Nitrogen - - -	1·866
Oxygen - - -	1·066
	4·000 [x]

The large proportion of nitrogen in urea leads to the conclusion that the kidneys are the great outlet for azote, as the lungs and liver are for carbon.

In disease, the specific gravity may exceed 1050, and the quantity has been greater than thirty pounds a day. Dr. Peter Frank had a patient who made forty pounds every twenty-four hours, and occasionally fifty-two pounds [a]; and he knew it exceed the weight of the body in a few days. On the other hand, no urine has sometimes been secreted for twenty-two weeks.[y] Dr. Richardson mentions a lad of seventeen who had never made any, and yet felt no inconvenience.[z] In disease, and even during such little derangements as are scarcely considered disease, the urine deposits sediments, lateritious and pink; and Dr. Prout has shown that they consist chiefly of the urate of ammonia, and states that they are formed from the albuminous portions of the chyle. The red colour he has shown to depend upon the presence of the purpurate of ammonia, — a substance formed from the uric acid, and which, like the other purpurates, colours the urates pink. When the usual yellow colouring matter is present, this, with the pink,

[x] *Med. Chir. Trans.* vol. viii. p. 535.

[y] Haller, *Biblioth. Medic.* vol. ii. p. 200.

[z] *Phil. Trans.* 1713. He had a constant diarrhœa.

[a] *De curandis hominum morbis*, lib. v. p. 44.

causes the sediment to be red —of various hues, according to the proportions; and, when the colouring matter is absent, as in hectic, the sediment is pink.[b]

Various odorous and coloured principles pass off with the urine; as turpentine, balsams, asparagus, on the one hand, and red fruits, cactus opuntia, rhubarb, indigo, &c. on the other. Mercury, iron, and prussiate of potass will enter into it; as well as tartaric, oxalic, gallic, succinic, benzoic, malic, and citric acids, or at least these will render it acid. Alkaline borates, carbonates, silicates, chlorates, and nitrates, also pass off by the kidney. But the neutral salts of potass and soda with vegetable acids are decomposed; the alkali only, in the state of carbonate, being found in the urine. Mineral acids, alcohol, camphor, empyreumatic animal oil, musk, cochineal, turnsol, le vert de vessie, and orcanette, with the oxides of iron, and preparations of lead and bismuth, when taken, are not found in it.[c]

The urine may be deranged as remarkably as the sweat. For it is sometimes blue, from containing indigo not taken into the system, as I have seen through the kindness of Dr. Prout, and from other substances; and blueness of it appears to be produced sometimes by Prussian blue swallowed. Sometimes it is black, perhaps from containing a peculiar acid, called melanic, without any danger to the health. Dr. Prout has shown me two specimens of this, in which the sediment was perfectly black; and it may contain not only the albumen and red particles of the blood, but absolutely sugar, and occasionally new substances found nowhere else.

The urine of birds is generally discharged with the fæces, becomes solid by exposure to the air, and contains a large quantity of biurate of ammonia. Urea exists in the urine of carnivorous birds, not in that of the herbivorous. Dr. Wollaston found the uric acid to be only $\frac{1}{200}$ in a goose feeding on nothing but grass; and in birds taking nothing but animal food, to constitute nearly the whole mass. That of serpents is discharged only once in some weeks, is of a caseous consistence, and likewise becomes perfectly solid afterwards. It is almost entirely uric acid, and superurates of potass, soda, and ammonia.[d] The urine of the turtle

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[b] Gultstonian Lectures delivered before the College of Physicians. *London Med. Gazette*, 1833.

[c] Berzelius, l. c.

[d] Dr. Prout, *Thomson's Annals of Philosophy*. Dr. Davy, *Phil. Trans.* 1813.

and tortoise is also destitute of urea, but does not contain urate of ammonia so pure. That of the frog and toad contains urea, chloride of sodium, and a little phosphate of lime.[e] The urine of fish, as well as of birds and reptiles, and the kidneys of mollusca, contain uric acid.[f] In oviparous animals the urine is formed from venous blood, the kidneys having a double venous circulation, exactly as is the case with the human liver.[g]

The urine of carnivorous mammalia contains uric acid and urea; while that of herbivorous brutes contains uro-benzoates and urea, but no uric acid, and is generally deficient in phosphates, which are replaced by carbonates.

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[e] Consult Berzelius, l. c.

[f] Ibid.

[g] Dr. Jacobson, *De system. venos. peculiari in permultis animalibus observato.* Hafniæ, 1821; and *Edinb. Med. and Surg. Journ.* vol. xix. p. 78.

CHAP. XVIII.

THE FAT.

In many parts of the body a fluid exists, which must be considered before we close our account of the production, application, and purification of the blood — or, in other words, of the natural functions. The *fat*, in truth, nourishes the body, when food cannot be procured or cannot be assimilated.

"The *fat*[a] is" a yellow "oily fluid, very similar in its general character to vegetable oils[b], bland, inodorous, lighter than water; containing" oleine, stearine, glycerine, and margaric and oleic acids — substances, together with some others, found in the fatty secretions of different animals. Stearine is the solid principle, and oleine the fluid principle, of oils. It consists ultimately of carbon, oxygen, and hydrogen.

Carbon - -	79·000
Oxygen - -	9·584
Hydrogen - -	11·416

"When secreted from the blood and deposited in the mucous tela, it exists in the form of drops, divided by the laminæ of the tela, in a manner not unlike that in which the vitreous humour of the eye is contained in very similar cells.

"The relation of fat to different parts is various.

"In the first place, some parts, even those whose mucous tela is extremely soft and delicate, never contain fat. Such are the palpebræ and penis.

"In very many parts, it is diffused indefinitely, especially in the *panniculus adiposus*, the interstices of the muscles, &c.

"In some few, it is always found, and appears to be contained in certain definite spaces, and destined for particular purposes. Such we consider the fat around the basis of the heart[c]: and in

[a] "W. Xav. Jansen, *Pinguedinis Animalis Consideratio Physiologica et Pathologica.* Lugd. Bat. 1784. 8vo."

[b] "J. D. Brandis, *Comm.* (rewarded with the royal prize) *de oleor. unguinosor. natura.* Gotting. 1785. 4to. p. 13."

[c] "Hence it is clear how many exceptions must be made to the assertion of

the mons veneris, where it forms a peculiar and circumscribed lump.[d]

"Its consistence varies in different parts. More fluid in the orbit, it is harder and more like suet around the kidneys.

"It is of late formation in the fœtus; scarcely any trace of its existence is discoverable before the fifth month after conception."

It is accumulated under the skin chiefly in the first years of childhood, and again between the fortieth year and old age. Women grow fat earlier, and especially if married. In old people it gradually lessens, like all solids and fluids, till they are wrinkled, shrivelled, and very light.

"There have been controversies respecting the mode of its secretion: some, as W. Hunter, contending that it is formed by peculiar glands; others, that it merely transudes from the arteries. Besides other arguments in favour of the latter opinion, we may urge the morbid existence of fat in parts naturally destitute of it; — a fact more explicable on the supposition of diseased action of vessels, than of the preternatural formation of glands. Thus, it is occasionally formed in the globe of the eye; a lump of hard fat generally fills up the place of an extirpated testicle; and steatoms have been found in almost every cavity of the body."

Dr. William Hunter contended that the fat is not contained in the same cells of the cellular membrane as the fluid of anasarca, but in distinct vesicles: because, — 1. The marrow, which strongly resembles fat, is contained in vesicles or bags; 2. Parts which are not loaded with anasarca, as the eyelids, never contain fat; 3. In dropsical subjects, exhausted of the fat, the membrane which contained fat appears still very different from the other, — that immediately under the skin, for example, being thin and collapsed, while that opposite the tendon of the latissimus dorsi is thick and gelatinous; 4. Parts which become filled with fluid from gravitation in dropsy, as the penis and scrotum, never contain a drop of oil in the fattest persons; 5. Dropsical parts pit on pressure; the fluid disperses, and returns when the pressure

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the celebrated Fourcroy, — that fat is an oily matter, formed at the extremities of arteries, and at the greatest distance from the centre of motion and animal heat. See his *Philosophie Chimique*, p. 112."

[d] "I found this still more distinct in the body of a female of the species *simia cynomolgus*, from which, by means of cold, I was able to remove it with its symmetrical form entire."

is resumed. This is not the case with parts distended by fat, although it is when oil is poured into the common cellular membrane after death.[c]

The intestines occasionally discharge fat; sometimes solid, sometimes fluid, but concreting quickly on cooling. I have seen such cases, and published a full history of the subject two years ago.[f]

" The glands which some celebrated characters have contended secrete the fat, are only imaginary.[g]

" Whatever may be the truth of this matter, the deposition and absorption of the fat take place with great rapidity.

" The use of the fat is multifarious.

" It lubricates the solids and facilitates their movements; prevents excessive sensibility; and, by equally distending the skin, contributes to beauty." It probably supports mechanically, and lessens shocks; and preserves the temperature of the body, like an inner garment.

" We pass over the particular uses of fat in certain parts, *v. c.* of the marrow of the bones.

" During health, it contributes little or nothing to nourishment."[h] But as soon as food or chyle is deficient, or great evacuations occur, it is absorbed, in order to afford as much nourishment as possible.

Fourcroy fancied " that it affords a receptacle for the super-

Medical Observations and Inquiries, vol. ii. p. 33. sqq.

Med. Chir. Trans. vol. xviii. I give cases of its discharge from both bowels and urinary bladder: and one of its discharge from the intestines, while the kidneys were discharging sugar and the lungs pus. Ambergris is a fatty matter found in the intestines of the spermaceti whale, but never higher than six or seven feet from the anus. Its quantity has exceeded a hundred pounds, and, though so frequently discharged as to be found on the shore and floating on the waves, accumulation, or the state which occasions it, sometimes appears to destroy life. It is more abundant in proportion as the animal is costive and sickly. l. c.

Some birds nourish their young with an oily substance, secreted in their own stomachs. This is so copious in the petrel, that, in the Faro Isles, people use petrels for candles, merely passing a wick through the body from the mouth to the rump. *Pennant, Brit. Zool.* vol. ii. p. 434.

[g] " The singular opinion of the distinguished Home, respecting the origin and use of the fat, *viz.* that it is formed in the large intestines, chiefly by the instrumentality of the bile, and that it supplies a kind of secondary nourishment to the body, will be found fully described in the *Phil. Trans.* 1813. p. 146."

[h] " P. Lyonet conjectures, with probability, that insects destitute of blood derive their chief nourishment from the fat in which they abound. *Tr. anat. de la Chenille qui ronge le bois de Saule,* pp. 428. 483. sq. and the Preface, p. xiii."

fluous hydrogen, which could not otherwise be easily evacuated."[i]

The fattest person on record is, I believe, Lambert of Leicester. He weighed seven hundred and thirty-nine pounds[k], and died at the age of forty years. In him rats and mice might certainly have nested, if it is true that a bishop of Mentz, or

> "A Saxon Duke, did grow so fat
> That mice (as histories relate)
> Ate grots and labyrinths to dwell in
> His postique parts without his feeling."[l]

Excessive formation of fat may be strongly opposed by regularly taking great exercise, little sleep, and little, but dry, food.[m] Fretfulness of temper, or real anxiety of mind, will prevent any one from getting fat, and make any fat man thin. A passage that occurs in the most magnificent of Shakspeare's Roman plays, and is founded on some information of Plutarch's, will instantly be remembered.

> *Cæsar.* Let me have men about me that are fat;
> Sleek-headed men, and such as sleep o' nights;
> Yond' Cassius has a lean and hungry look;
> He thinks too much: such men are dangerous.
> *Antony.* Fear him not, Cæsar, he 's not dangerous;
> He is a noble Roman, and well given.
> *Cæsar.* 'Would he were fatter:— But I fear him not:
> Yet if my name were liable to fear,
> I do not know the man I should avoid
> So soon as that spare Cassius.[n]

Great obesity occurs sometimes in infants. I saw a prodigiously fat female, but a year old, who weighed sixty pounds, and

[i] "See Fourcroy, l. c.

[k] Dr. Good says that some German Journals mention cases of eight hundred pounds weight, but he gives no references.

[l] *Hudibras*, P. ii. Canto i.

[m] Semper vero et certissime debellanda (obesitas), si modo bona voluntas et vis animi fuerit, valida corporis exercitatione, brevi somno, parca et sicca diæta. Nec facile miles gregarius repertus fuerit, qui tali morbo laborat. Dr. Gregory, *Conspectus Med. Theor.* lxxxix. Iodine is the best *medicine* against it.

See the intructive case of the Miller of Billericay, in the *Transactions of the Royal College of Physicians, London*, vol. ii.

A large collection of cases of obesity will be found in Mr. Wadd's *Cursory Remarks on Corpulence.*

[n] *Julius Cæsar*, act i. scene 2.

had begun to grow fat at the end of the third month. She was also of Herculean general development, and, like many dwarfs, had a flat nose. At an early age I believe females are more commonly the subjects of the affection than males.

A Frenchman named Seurat, who was shown in London a few years ago, with the soubriquet of the "Living Skeleton," was probably as extreme an instance of emaciation as can be imagined. An American, named Calvin Edson, shown more lately, was also extraordinarily emaciated, and weighed but 58 lbs. They had no other apparent disease. The Frenchman was about 30 years old, and had wasted from infancy: the American about 40, and had wasted for sixteen years. A French penny roll and a little *vin du pays* was the Frenchman's daily food in France; and in England a little meat, amounting, with a reduced portion of bread, to three ounces per diem.

The fatty substance of various animals has various properties, and affords various principles. Vegetables contain fatty substances volatile as well as fixed.

Starch is hoarded in plants in small cells, into which the sap penetrates and then dissolves it, so that it becomes nourishment to the plant, under particular circumstances, just as fat does to animals. This is the purpose of the stock of fecula in tuberose roots.